ELEMENTARY
PHYSICAL GEOGRAPHY

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AN OUTLINE OF PHYSIOGRAPHY

BY

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"*The waste of the Old Land is the material of the New*"

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PREFACE

The science of Geography sets forth the relations of life and its environment to the earth, and it is the function of both the writer and the teacher of geography to explain these relations. In the Elementary Natural Geography the pupil studies the various peoples of the earth and the countries in which they live; in the Advanced Geography there is presented in addition a discussion of the industries of life and their geographic distribution. In the present volume, which the author has prepared as a logical sequel, it is designed to show that the distribution of life is governed very largely by the conditions of geographic environment, and that human history and industries are always closely connected with geographic laws —in many instances the direct resultants of them.

The science of Geography as now understood includes something more than a mere description of topographic forms—it comprehends the gradual and progressive development of these forms and their results as regards life, as well. It includes also the effects of temperature and moisture, for life and its activities depend also on them. That is, it naturally involves the principles of Descriptive Geography, Physiography, and Economics; and the present volume is designed to show their interrelation.

In scope this book contains all the principles recommended by the Committee of Fifteen, and such other features as have suggested themselves to the author. It is designed to be used in the junior grades of the High

School, and in Normal Schools. With judgment in the selection of the topics, it may be begun in the last half of the eighth year of the Grammar School. The arrangement of the subjects is logical, but the teacher may readily organize a course of study in the subject without reference to the present arrangement. To make this more easily accomplished, the *principles* of the subject are set forth in the larger type; relevant matter that is illustrative but non-essential is confined to the notes. In general, the teacher should not hesitate to omit a topic the discussion of which is too difficult for the class.

The Questions and Exercises are designed to stimulate observation and independent thought. If, occasionally, they leave the pupil in doubt, the design of the author will be fulfilled. The pupil must learn by experience that knowledge does not come in cut-and-dried packages.

In the preparation of the work the author takes pleasure in acknowledging the material assistance of Miss Frances Bronson, and of his daughter, Miss Elizabeth Ebert Redway. But to more than anyone else, however, thanks are due to Miss Stella Wilson, Instructor in Physical Geography in the Central High School, Columbus, Ohio. To Miss Wilson's keen judgment, excellent criticism, and experience are largely due the usefulness as a text-book which this volume may have.

The books designated for reference and collateral reading are intentionally few in number, and those most commonly cited should be in the school library. The teacher will also find it very advisable to get in close touch with the United States Geological Survey and the Weather Bureau. The Bureau of Geography recently established at Winona, Minn., will also be helpful.

J. W. R.

CONTENTS

LIST OF MAPS AND PLATES

PHYSICAL GEOGRAPHY

INTRODUCTORY

ONLY a casual thought is needed to make it apparent that life on the earth, as we now find it, depends on a very delicate adjustment to its surroundings. Living beings require certain conditions of heat, moisture, and geographic environment; and if these are changed ever so slightly the life forms must adjust themselves to the new conditions, or else they must seek a new abiding-place; or, perhaps, they may perish altogether.

For instance, turf grass requires water at very short intervals, and if for several successive years there are droughts of five or six months' duration, it will die. And if there are herds of cattle in the region, they must adjust themselves to the changed conditions. They must adapt themselves to other food, or they must migrate. Otherwise they too will perish.

Were the temperature of the earth to change only a few degrees there would be a similar disturbance that would involve almost every living thing. And if it should fall so low that the water were everywhere frozen, life as we now know it could not exist any great length of time, because living beings need in their structure a large proportion of water, and the latter must be taken into the structure in a liquid form. For a similar reason, if all the water were in the form of vapor, life could not long endure unless the

life forms were very different in structure from those with which we are acquainted.

Life is by no means evenly distributed over the earth, however. A few species spend the greater part of their existence in the air, and a larger number live in water only. By far the greater number of species, however, live at the plane of contact between the atmosphere and the earth's

A FERTILE VALLEY, NEW YORK

Capable of producing abundant food-stuffs, and densely peopled.

rock envelope—that is, on the land surface of the earth. Their distribution is governed by the conditions of warmth, moisture, and surface, and if these conditions were to change ever so slightly, the distribution would be disturbed. Life and its distribution are governed by geographic laws; if the latter change, so must the former.

Man, who stands at the head of animate nature, is able to endure a much wider range of warmth, moisture, and

surface features than most other living beings. He can withstand extremes of heat and cold that are fatal to most other animals, and he can live indifferently in places of great drought or of excessive moisture. The arctic regions are not so cold, nor the tropical lands so hot that man cannot dwell there; and throughout the wide world one can find scarcely an ice-clad summit or a sun-beaten desert in which human beings have not lived.

On account of these varying conditions—all the result of geographic laws—the study of the earth is both important and interesting, because it is the home of man. Like all forms of life, man requires food; more than any other animal, he needs shelter. His food, of which he consumes about eighty tons during the three or four score years of his existence, comes from the earth—the land, the water, and the air each yielding part—and the materials that are used for clothing and shelter come also from the same source—the earth.

So, in order to understand the story of life, its history and its industries, one must learn about the physical geography of its surroundings—that is, about its environment, or the various conditions of heat, moisture, and surface features. Land animals could not live until the waters were separated from the land. Before they could maintain life, vegetation must have spread itself over the land; and before vegetation could endure there must have been soil. And before there could be soil, the surface of the land must have been folded, broken, worn, and furrowed, so that the fragments of rock could be ground fine and formed into soil. All these earth-weathering processes must have been going on before the higher forms of life could exist, and all over the surface of the land such changes are even now going on from day to day. Scarcely a summer shower falls that does not leave its marks; and,

indeed, throughout the physical history of the earth the most apparent feature is constant change.

From the time the land was first divided from the waters, the continents, or great bodies of land have been ever changing. In places, alternately sinking, rising, and warping in various ways, the shore outlines have taken various forms. Rugged coasts sinking below sea-level have resulted in the fjorded shores, such as those of the

ARCTIC LANDS

Too cold and not enough soil for the support of life.

North Atlantic States, making the harbors where so much of the manufacture and commerce of the country have centred. Rising coasts have lifted natural harbors above sea-level, making the approaches to the land so difficult that vessels can find no sheltered anchorage. Old sea-bottoms, covered with sediments that form the richest soil, have been lifted above the sea, and in time have become densely peopled areas.

Certain forces are causing the surface of the rock envelope to wrinkle and fold, forming plateaus, mountains, and valleys; and at the same time the waters of the atmosphere, falling as rain or snow, are constantly at work wearing away the wrinkles and folds, carrying the material back to the sea.

It is necessary to know about these processes, and to understand how they are going on, because almost every form of life is more or less modified by them, and certainly the history and the industries of man are very largely governed by them. Man may rise superior to his environment—that is, his geographic surroundings—but he is always more or less modified by it. Mountains and valleys, plains and plateaus, oceans and rivers, have all been potent factors in making the destiny of peoples.

The rugged and barren slope of Norway forbade any great development of agriculture, while the deeply fjorded shores invited the pursuits of the sea. The Norse people, therefore, became sea rovers and magnificent sailors. The uncultivable mountains of Greece could not well yield the food-stuffs necessary for the population, so we find a history of "Greece scattered." From the remotest times the rich valley of the Tigris and Euphrates, because of its fertility, has always attracted people, and we therefore find it a densely settled region.

Unless there is something to unfit them for human habitation, lowlands are favorite places of dwelling, and by far the greater part of the world's population is found in them. How is the statement borne out in the case of the Central Plain of North America?—the swampy, forest plain of the Amazon?—the great lowland region of southeastern Asia?—the northern plains of Eurasia?

River bottom-lands, also, are nearly always densely peopled. How is this illustrated in the history of Egypt?—

with regard to the nations dwelling in the Mesopotamia? —the valley of the Ganges?—the bottom-lands of the Mississippi River?—the Sacramento-San Joaquin Valley? Extensive desert regions are always sparsely peopled

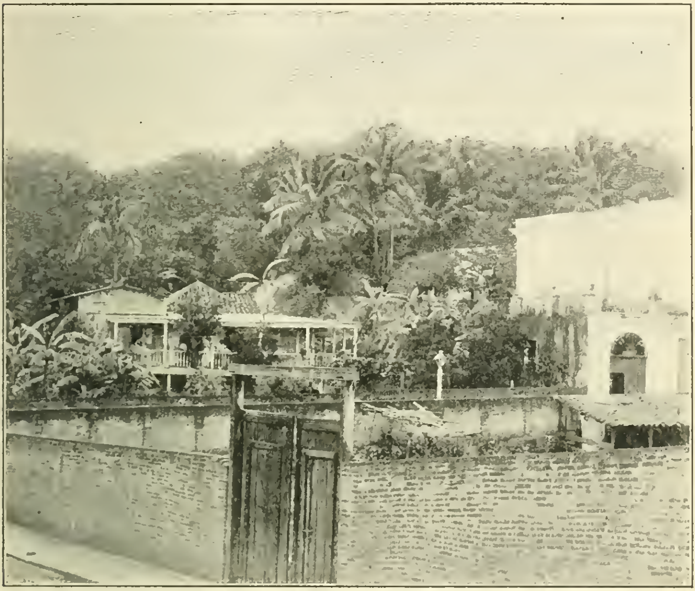
A RUGGED NORWEGIAN SLOPE

A locality not suitable for farming; a few food-plants may be grown.

why? How is this illustrated in the eastern and western halves of the United States? The population of rugged highlands and mountain ranges is usually sparse; is there a good reason therefor?

The hot regions of the land are almost always densely peopled, the deserts and forest swamps excepted. Is this

true of the intensely cold regions? Life thrives best in regions of warmth and of strong sunlight. Are all parts of the earth equally warmed? Have all parts the same intensity of light? Compare the density of population of



A TROPICAL SCENE

Both temperature and moisture are favorable to a great productivity of food-stuffs.

cold and dimly lighted parts of the earth with that of the warm and strongly lighted parts: in which is it greatest?

The study of the distribution of heat and cold, of rain and drought, of highlands and lowlands, and of fertile and unfertile regions form an essential part of the study of geography; the study of the progressive changes that have been and are now taking place on the earth's surface constitutes the science of physiography, or "nature-writing."

The object of this book is to show that the fundamental laws of geographic science not only control the structure of life forms and their distribution over the earth, but that they also largely control and modify the history, the activities, and the various economies of man, as well.

QUESTIONS AND EXERCISES.—What are the leading industries of the city or town in which you live? Note and describe a geographic feature that favors any one of these industries, and without which the industry could not thrive.

What would be the effect, so far as the habitability of the surrounding region is concerned, were the rainfall to be diminished one-half?

How would a material change in the surface features affect the industries?

On p. 369 is a map of New York Harbor; what would be the effect on the commerce of the port if the surface of the water were lowered two hundred feet?

Mention two or more reasons why lowland regions are more densely peopled than highlands.

Quito, the capital of Ecuador, is in the midst of a fertile region nearly two miles above sea-level; what are its advantages over the coast plain region to the westward?

Make a list of half-a-dozen or more extensive regions that are not habitable, and explain the geographic reasons for their condition.

COLLATERAL READING.

MILL.—Realm of Nature, pp. 331–336.
SHALER.—Nature and Man in North America.

CHAPTER I

THE EARTH AMONG PLANETS

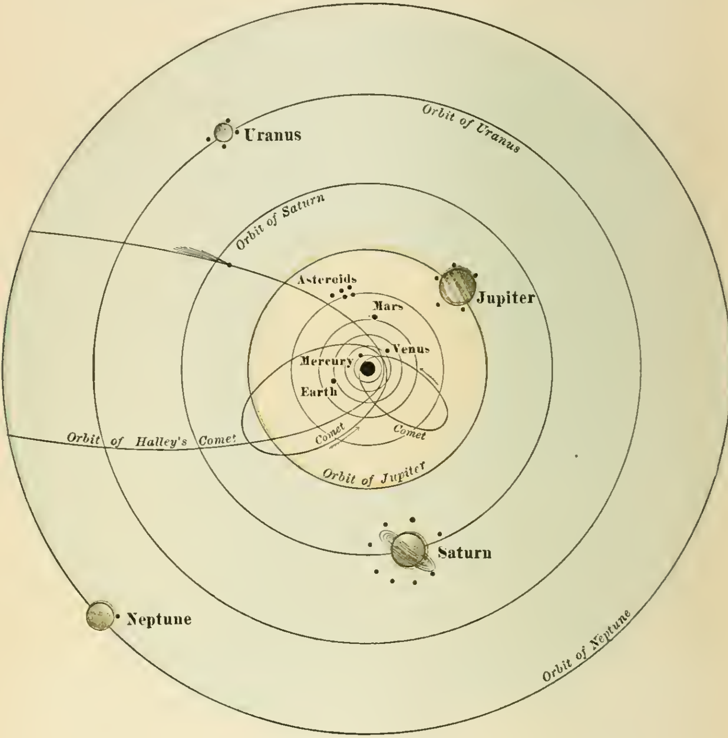
The Solar System.—The cluster of heavenly bodies called the solar system is one of a great number of groups in space. The members of this group revolve about a common centre of gravity, however, and for this reason they are called collectively a *system*. The number of bodies composing it is unknown.

The members of this system vary greatly in size. The largest is about 886,000 miles in diameter, and the smallest are probably too minute to be measured by ordinary standards. Eight of them, however, are three thousand miles, more or less, in diameter, and a large number, about four hundred, vary from ten miles to less than five hundred in diameter.

The largest member of the solar system, the sun, is about eight hundred times as large as all the others together, and the common centre of gravity around which they revolve is very near to it or, perhaps, within its mass. The eight bodies next in size are called *planets*, and all but two of them are attended each by one or more *satellites* or *moons*. The four hundred or more small planets are called *asteroids*,[1] or, more properly, *planetoids*. In addition there are several *comets*[2] and groups of *meteors*[3] that have a permanent place in the solar system.

There is much evidence to show that the planets are composed of the same kinds of substance or material, but it seems certain that they are very unlike one another in

physical condition; for while some, bulk for bulk, are but little heavier than water, others are about as heavy as iron ore. It seems certain also that this difference is largely a result of temperature; for while some of the planets have

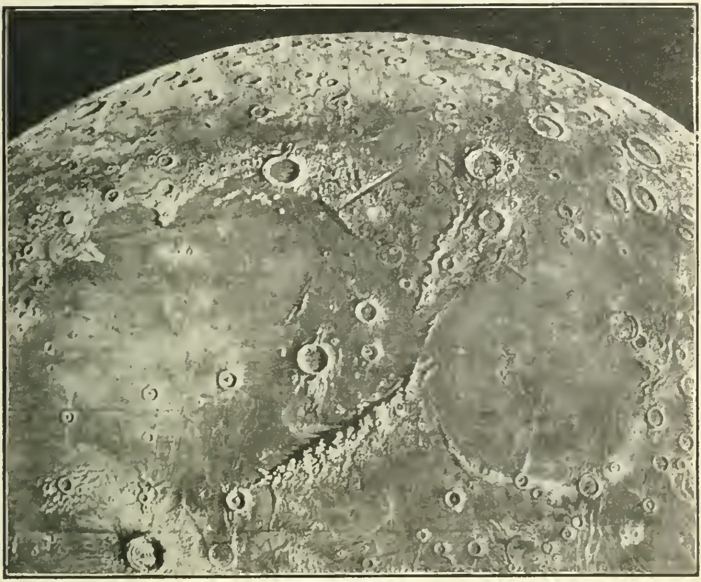


THE SOLAR SYSTEM

The space within the orbit of Jupiter shows the relative size of the Sun.

apparently lost the greater part of their heat, others still are very hot. The sun, for instance, is a glowing mass surrounded by white-hot vapors, and its heat is probably greater than any artificial heat known.

The Sun and the Planets.—The similarity of the sun and the planets to one another is far more marked than their points of difference. All whirl around a common centre of gravity in a direction from west to east, and each turns or spins on its axis in the same direction. Each is nearly spherical in shape, differing from a sphere by a



A PORTION OF THE MOON

From a photograph.

curvature that in nearly every instance is a slight flattening at the poles of their axes. Several are known to be surrounded each with an atmosphere, and there is some evidence that this is true of all.

It is now generally believed that the members of the solar system formerly existed as a body of gaseous matter;[1] because the force of gravity drew the particles together,

toward the centre of gravity, a rotation of the mass around the centre of gravity resulted. Finally, parts of the mass were thrown off, one after another, forming the planets. In the same manner, the rapid rotation of each planet threw off portions of its mass forming the satellites.

Although the assumed formation of the solar system by this process is a matter of theory, it is a theory supported by evidence. The telescope reveals many such masses of gaseous matter showing planetary formation. The spectroscope, an instrument for analyzing light, shows, not only the matter of which they are composed, but also that the matter is in rapid motion. It shows also that the earth and the sun contain the *same kinds* of matter. Calcium, hydrogen, iron, and sodium, the substances of greatest abundance at the surface of the sun, are also among the most abundant substances in the composition of the earth.

+ **The Form of the Earth.**—The earth is one of the planets. From Table I. (*Appendix*), find how it ranks among the other planets in size;—in distance from the sun. In form the earth resembles the other planets, being nearly spherical, but slightly flattened at the poles. It is usually said to be an *oblate spheroid*—that is, a sphere flattened at its polar diameter, but it deviates slightly from this form; hence the term *geoid* is sometimes used to apply to its irregular shape.

The spherical form of the earth is shown in various ways that are well known, but it is demonstrated most clearly by surveying a horizontal straight line along a level surface, such as that *of a pond.*[5] The line thus projected does not lie parallel to the surface; the latter recedes or curves away from it, and the curvature is such as corresponds to the surface of a spherical body.

Were the earth a true sphere, the weight of a body would be the same at every part of its surface. There is

a measurable difference, however,[6] and it is found that a given body weighs a little more in polar than in equatorial latitudes, and from the careful experiments based on this fact the amount of flattening at the poles has been determined.

The following are its dimensions:

Polar diameter	7,901.5 miles
Equatorial diameter	7,926.6 miles
Circumference at equator	24,912 2 miles
Surface (approximate)	197,000,000 square miles

What is the difference between the polar and the equatorial diameter? On a globe one foot in diameter the difference would be what part of one inch? Compare the diameter of the earth with that of the sun (Table I., *Appendix*). Large as the earth seems to us, it would require about one and a quarter million bodies of its size to make a globe as large as the sun.

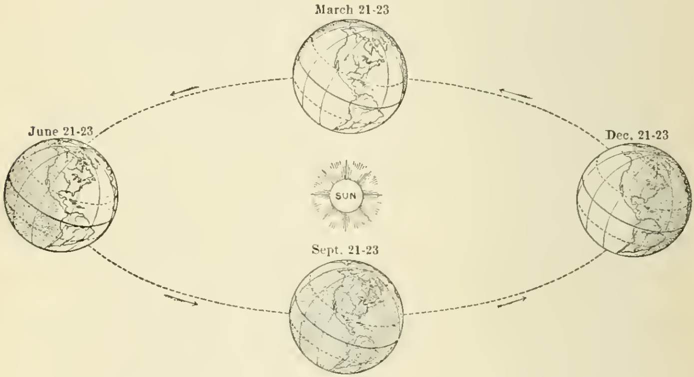
Motions.—The earth has several distinct motions. It revolves about the common centre of gravity in an elliptical path, making a complete journey in very nearly $365\frac{1}{4}$ days—a period of time called a *year*. It also rotates, or spins on its axis. The time required to make a complete rotation is called a *day* and is commonly used as a unit for the measurement of short intervals of time. The poles of the earth also move or oscillate in a nearly circular path. The motion resembles that of the poles of a "sleeping" top.

The first motion combined with the inclination of the axis gives rise to the successive change of the seasons and the varying length of sunshine and darkness. The second motion causes the succession of day and night; it is "day" in all parts of the surface turned toward the sun and "night" on the opposite side. The third motion causes the phenomenon or movement commonly known as the *pre-*

cession of the equinoxes. In long intervals of time it is thought that this motion is connected with certain changes of climate. It is a subject, however, that belongs to the science of astronomy, and not to physical geography.

Effects of the Inclination of the Axis.—The axis of the earth is not perpendicular to the earth's path (called the *plane of the ecliptic*), but inclines about 23½ degrees, as shown in the accompanying figure. In long intervals of time the amount of inclination varies. Practically, however, the axis points always in the same direction and therefore is said to be parallel to itself. The northern end of the axis prolonged would extend nearly in the direction of a star named Polaris; this star is therefore often called the *north star.*

If the earth's axis were perpendicular to the plane of its orbit, each place would have the same unvarying season.



INCLINATION OF THE EARTH'S AXIS

The unshaded hemisphere shows the position of the light circle at each of the four seasons.

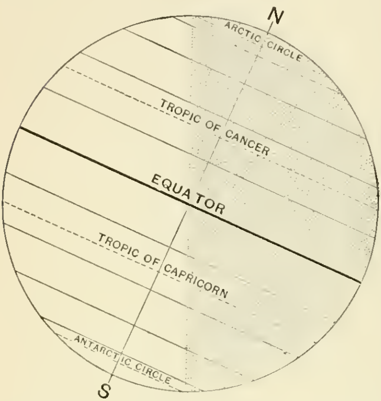
It would be hot in equatorial regions, mild in mid-latitudes, and cold in polar regions, the intensity of heat increasing from the poles toward the equator.

With the axis inclined, however, the case is different. An inspection of the accompanying diagram shows that during the month of June the sun's rays fall almost vertically on mid-latitude parts of the Northern Hemisphere, while in the corresponding latitudes of the Southern Hemisphere the rays are very oblique. At this season, therefore the Northern Hemisphere receives more light and more heat than the Southern.

Six months later the conditions are reversed; the belt of vertical and nearly vertical rays is in the Southern Hemisphere, while in the Northern, the rays of light and heat are very oblique. At this season, therefore, the Southern Hemisphere receives its greatest warmth. Thus, it is seen, the amount of light and warmth received by each hemisphere varies. In equatorial latitudes the difference is not great, but beyond the tropics, in higher latitudes, it is the difference between winter and summer. In polar latitudes the sun is shining the greater part of the time for six months alternately in each hemisphere, the other hemisphere being in darkness. As a result the season of sunshine, or summer, becomes oppressively hot at times, while the season of darkness, or winter, is intensely cold.

The rotation or spinning of the earth on its axis causes the succession of day-light and darkness, or, popularly, "day" and "night." One-half the surface, being always toward the sun, is therefore illuminated, while the opposite side is in darkness. The rotation of the earth, however, presents every part successively toward the sun, lighting all parts in turn. Were the axis of the earth perpendicular to the direction of the light-rays, day and night would be of equal duration in all parts of the earth's surface; but on account of its inclination, the relative length varies, not only in different latitudes, but with the changes of the seasons in the same latitude.

In the torrid zone the period of daylight and darkness does not vary much from twelve hours each, and at the equator each is twelve hours long through the year. In the temperate zones the days are longest near the polar circles and shortest near the tropics, varying from thirteen to twenty-four hours. Within the frigid zone day and night correspond practically to summer and winter. There, both the day and the night vary from a few brief moments to six months in length.



RELATIVE LENGTH OF DAY AND NIGHT

The shaded part of each parallel shows the length of the night; the unshaded part, the proportionate length of the day.

The relative length of daylight and darkness and the changes of the seasons have much to do with the subject of physiography. For their vitality almost all the forms of life depend not only on the presence of sunlight, but on the time and manner of distribution as well. Only a very few species of animals and plants thrive in regions of long-continued darkness, and they are mainly the lower forms; the higher species require an environment in which light and darkness follow one after the other in periods of short duration. With few exceptions, plants fail to mature and fructify unless exposed to strong light, and many species will not live at all. Plants that are forced into blossom in darkened rooms have usually pale or white flowers, and the leaves of growing plants are apt to be yellow instead of green.

QUESTIONS AND EXERCISES.—Make a circle one inch in diameter on the blackboard, and from the centre of this circle, with a radius fifty-five inches long, draw as much of the arc of a circle as the size of the blackboard will permit. The two circles represent the relative size of the earth and the sun.

In the diagram, p. 14, the axis of the earth is inclined 23½ degrees from the dotted line; which of these positions represents summer in the Northern Hemisphere?—In the Southern? Copy the diagram, p. 16, and mark the point the sun's rays reach beyond the north pole; how many degrees from the pole to this point? What circle passes through this point? Mark the point on the circumference where the rays are vertical. What circle passes through this point? From each pole to the equator the angular distance is ninety degrees: find the distance in degrees from the Arctic Circle to the Tropic of Cancer; this distance is the width of the Temperate Zone. If the inclination of axis were 28 degrees, what would be the width of each light-zone? If 32 degrees? Ninety degrees less twice the angle of inclination equals the width of the Temperate Zone.

In the diagram, p. 16, the proportionate length of the longest day and shortest night are shown by the shading: determine by measurement the length of the longest day in latitude 40°; in latitude 60°. *Subdivide the parallel into twenty-four parts by halving it three times and dividing the last subdivisions each into three parts; each of the smallest subdivisions has practically an hour value.*

COLLATERAL READING AND REFERENCE.

MILL.—Realm of Nature, pp. 63–81.
REDWAY.—Manual of Geography, pp. 64–78.
HOWE.—Elements of Astronomy. Problems, *a–g*, p. 83.
JACKSON.—Astronomical Geography.

NOTES

[1] The asteroids move in orbits in the space between Mars and Jupiter. Many of them do not exceed twenty or thirty miles in diameter, and the largest probably does not exceed five hundred miles. Their combined volume is less than one four-thousandth part of the mass of the earth. Eros, one of the recently discovered asteroids, has an orbit so eccentric that it crosses that of Mars, and at times is nearer to the earth than is Mars.

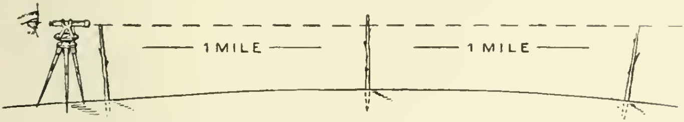
[2] But little is known about the nature and structure of comets, but it is thought that the chief part of their masses, in most instances, is gaseous matter. One comet, Tempel's, undoubtedly consists of a vast swarm of meteors, but it is probable that the various comets are differently constituted. Several of them belong to the solar system, but many are temporary visitors, coming from unknown regions of space, whirling around the sun and again vanishing.

[3] Meteors, or shooting stars, are small bodies that seem to exist very generally throughout space. In a few instances they are seen in clusters, as in the case of Tempel's comet. The earth, and probably the other planets, encounter many thousands of them daily, in sweeping through space. By far the greater number on reaching the earth's atmosphere are heated to whiteness—partly by compression of the atmosphere in front of it, and partly by friction against it—and are dissipated as white-hot vapor. Some of the larger ones reach the earth, and many of these have been analyzed. Some consist mainly of iron and nickel in a metallic form; others are composed of matter not differing materially from lavas. No element has yet been found in a meteor that does not occur in the earth, but in a few instances chemical compounds, of iron, nickel, and phosphorus, and certain crystalline forms, have been found in meteors that have never been met with naturally in terrestrial substances. In one instance gold, in another diamonds, were found in a meteorite.

[4] So far as is known, matter exists in three physical forms—solid, liquid, and gaseous—and nearly every chemical element and many of their compounds may assume each form. In the solid form the molecules are bound by a strong cohesion; in the liquid form they are very slightly cohesive; in the gaseous form they strongly repel one another. Most of the substances that in the earth are solids, in the sun exist as white-hot vapors.

[5] An interesting experiment is suggested by Professor Edward Jackson (Astronomical Geography, p. 3). Three stakes are in line, or as nearly in line as is practicable, one mile apart, along the shore of a canal or a pond. On these, sighting marks are made at a uniform distance above water-level. An engineer's level is then placed so that the cross-wires cut the sighting marks of the first and third stakes. If the telescope of the level be turned

upon the middle stake it will be found that the cross-wires cut the stake at a point eight inches below the sighting mark.



EXPERIMENT TO SHOW THE EARTH'S CURVATURE.

[6] It is by measurements depending on this principle that the exact shape of the earth has been ascertained. A pendulum of absolute uniform length, weighted by a cannon-ball weighing about one hundred pounds, is allowed to oscillate freely. When all errors are corrected the rate of vibration will be the same at all points of the earth's surface equally distant from the centre. At any part nearer the centre, as the poles, the rate of vibration is slightly faster ; at any place more remote they will be slower. The United States Coast and Geodetic Survey has carried on a series of pendulum observations covering a period of many years with the results noted on p. 12. Professor Ferrel has shown that, theoretically, the level of the sea between the 20th and 27th parallels is about thirteen metres (40 ft.) higher than it would be if the earth were a true spheroid.

[7] Any change in the inclination of the earth's axis would have the effect of producing decided changes of climate. For instance, if the inclination were increased, the limits of the frigid zones would be pushed farther toward the equator. That is, if the inclination of the axis were forty degrees instead of twenty-three and one-half, the polar circles would each be forty degrees from the poles, and the tropics would be each forty degrees from the equator.

CHAPTER II

THE STRUCTURE OF THE EARTH

In the long period of time that has elapsed since the earth was glowing with intense heat, the substances composing it seem to have adjusted themselves in accordance with the laws of gravitation[1]—that is, the heaviest kinds of

IDEAL SECTION THROUGH THE EARTH

The thickness of the various envelopes is greatly distorted.

matter are nearest the centre. Structurally the earth consists of a dense and practically solid globe, the *lithosphere*, nearly covered with a comparatively thin layer of water,

the *hydrosphere* or water envelope, the whole surrounded by an envelope of gaseous matter, the *atmosphere*.

The shape of the lithosphere and the condition of the substances composing it, all go to show that in times past it was intensely heated, and that much of the rock composing it has been in a molten condition. The globular form is the only one that would naturally result from the action of gravitation on a plastic or fluid body; and the flattening at the poles is most reasonably explained by the supposition of a rotation on its axis while it was still plastic.

The density of the lithosphere, together with the waters, is about that of iron ore[2]—that is, bulk for bulk, it is about five and one-half times as heavy as water. At the surface, however, the density of the rocks is not much more than half as great; it is certain, therefore, that the substances forming the interior are much heavier than those occurring at the surface.

The Rock Envelope.—The outer part of the lithosphere is a shell of more or less friable material called the *rock envelope*, or, popularly, the "crust of the earth." It surrounds an intensely heated interior.[3] The rock envelope itself has lost so much of the heat it once had that it is comparatively cold; the amount of heat it radiates is about equal to that which it receives from the sun.

That the interior of the lithosphere is very hot, however, cannot be doubted; for in every place where the rock envelope has been penetrated by deep borings, a constant increase of temperature is observed—the greater the depth the higher the temperature.[1] The thickness of the rock envelope is not known, but at a depth of less than forty miles it is thought that the temperature is high enough to fuse the most refractory substances. The broken folds of the outer surface have revealed something of its character to the depth of several miles. Borings have been made to a

depth of a little more than a mile (Table II., *Appendix*), but beyond the slight knowledge obtained from these, nothing positive is known about its interior.

The Water Envelope.—About four-fifths of the surface of the rock envelope is covered by a comparatively thin layer of water, the hydrosphere. The water not only exists in a free state, at the surface, but in chemical combination it is a constituent of various kinds of rock[5] that occur at or near the surface.

The waters of the earth form a most important constituent so far as life is concerned. Water is an essential element to the existence of life; for not only does it form the greater part of every plant or animal, but it is also the chief vehicle by which nutrition is distributed throughout the various parts of the body of the animal or the plant. Within a range of a very few degrees of temperature, water exists in one or another of three forms—a solid, ice; a liquid, water; and an invisible vapor, often called "steam." Water in one or the other of its forms is the agent by which, more than any other, the surface of the rock envelope has been sculptured; therefore it has a very important part in the science of physiography.

The Atmosphere.—The atmosphere consists of a mixture of gaseous substances—namely: nitrogen, oxygen, water vapor, and carbon dioxide. Of these oxygen is the substance required in the breathing of animals; carbon dioxide, the gas formed when coal or carbon "burns," is essential in the breathing of plants; nitrogen forms a part of the body structure in both animals and plants; and water vapor is the form in which the fresh water is carried from the sea to the land. The atmosphere, therefore, is just as essential to life as the water envelope.

The thickness of the atmospheric envelope is not known. Various estimates place it between one hundred and two

hundred miles. At the latter estimate, on a globe one yard in diameter, the depth of the atmosphere in proportion would be about one-half an inch.[6] Illustrate by diagram.

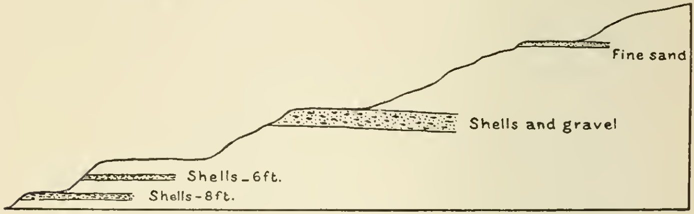
Keeping Nature's Balance.—The three envelopes are constantly acting and reacting upon each other, and at the same time each has certain movements of its own. The movements of the rock envelope have changed the level of its surface so that the waters are divided from the land, and the surface of the land has been wrinkled, crumpled, and folded so as to form the plateaus, ranges, and valleys. The heat of the sun causes a part of the ocean waters to take the form of vapor, and the latter, mingled with the air, flows over the land. Being chilled, the vapor again takes the form of rain, or of snow, and falling on the land wears away its surface. The water gathers into channels and, carrying the mingled particles of rock waste in its flood, flows back to the sea and there deposits them.

And so the cycle of change ever goes on. At the plane where the atmosphere rests upon the land and the sea the physiographic processes that modify the earth's surface are ever in action.

Vertical Movements of the Rock Envelope.—The changes in the surface of the rock envelope that are most noticeable are the wearing away of the land and the transportation of the rock waste to lower levels. That is, water falling as rain loosens particles of rock, while streams carry it seaward. If the land were everywhere level, the run-off of water could wear away but little of it; but vertical movements of the surface that are apparent only after long intervals of time are taking place, and these, making new slopes, have given the run-off waters increased wearing power.

Movements of the rock envelope in times past have diversified its surface with highlands and lowlands, moun-

tains and valleys, and similar movements are going on at the present time. Probably no part of the earth is free from them, but they are most clearly observed along sea-shores. Thus, the coast of New Jersey is sinking;[7] and



AN UPLIFTED COAST, SAN PEDRO, CAL.

From a survey made by Merick Reynolds, Jr. The successively formed beaches are shown by the strata of shells and sand.

so also is much of the coast around the Gulf of Mexico, the Zuyder Zee, and the delta of the Ganges-Brahmaputra. The coast of the New England Plateau has subsided until the sea has flooded the coast plain and the lower valleys, and has buried most of the old river mouths. The multitude of bays and fjords that characterize this coast are examples of "drowned" valleys. On the other hand, parts of the Mediterranean basin, of the California coast,[8] the Scandinavian peninsula, and the basin of Great Salt Lake are rising.

In nearly every instance in areas to which extensive sediments are being carried there is evidence of sinking; while, as a rule, areas that are being denuded are rising. It is evident, therefore, that vertical movements of the rock envelope—that is, uplift and subsidence—are definitely connected with the wasting of the land and the transfer of sediment.

The cause or causes of these earth movements are not known, but it is believed that the gradual contraction of the rock envelope to fit itself around a more rapidly shrink-

ing interior is the chief cause. There is evidence, too, that gravitation is a factor. The removal of great amounts of rock waste—often many cubic miles in volume—from one locality to another, relieves weight at one place and increases it at the other.[9] Therefore it is inferred that a sinking, because of the increased load, occurs at the latter place, and an uplift at the former, on account of the lessened weight.

The effects of these earth movements are very far-reaching. The great highland regions of the earth, with their ridges and folds, are probably direct results, and it is not improbable that the uplift of the continents themselves was also due to them.

IGNEOUS ROCK: A FLOW OF LAVA

Rock and Its Formation.—To almost every mineral substance that forms a part of the earth, the term *rock* is applied. Thus, clay, sand, gravel, limestone, quartz, granite, lava, and even the fine, wind-blown rock waste, are

each called rock; and so also is a combination or any mixture of them. In many instances there is no doubt at all how the rock has been formed, or whether it has been altered or not, because the whole process of its formation has been carried on in plain sight. Thus, when a volcano or a fissure pours out a flood of molten lava there is no question about how the rock got into place, or whence it came. The lava, when it has hardened, may be glassy, or metallic in appearance, or it may be like cinder or furnace slag; but there are always qualities about it that determine its origin.

Beyond a depth of a few thousand feet from the surface, nothing positive is known about the substances of which the rock envelope is composed. It is certain, however, that most of the rock now at the surface consists of sediments carried into place by running water and deposited in the form of layers or *strata* that afterward hardened into compact rock. But these sediments must have come from somewhere, and there is but one place from which they could be derived—namely, from the rock envelope itself.

Now, no one knows what the *primitive* or first rock that formed the crust of the earth may have been, but certain kinds of rock have been found underlying the water-formed sediments from which the latter seem to be derived. Ordinary granite is an example of this kind of rock, and granitic rocks are very abundant. There are various kinds of granite, but the most common varieties contain minerals of which nearly all the elementary rocks themselves are composed.

One of these minerals is *silica*, of which quartz and sea sand are the best examples. Another is *felspar*, a mineral which, decomposed, yields clay, potash, lime, and soda. Another mineral is *hornblende*, which decomposes mainly into iron, lime, and silica. Still another constituent usually

present is *mica*, popularly called "isinglass;" like felspar it also decomposes into clay, silica, lime, and a number of other substances.

EXERCISE.—Procure one or more specimens of granite,[10] and with the aid of a magnifying-glass observe the following directions. Look for small clusters of foliated or "leafy" mineral; it may be whitish or, perhaps, green or brown; this mineral is mica. If no mica is found, look for jet black crystals or masses; this is hornblende; it is usually opaque, but sometimes translucent. Find the white, translucent mineral with glassy lustre; it is quartz, or silica, and it is apt to form the chief bulk of the rock. Look also for an opaque mineral varying from yellowish-white to pink in color; possibly it will break into fragments having flat sides, or *cleavage planes;* this mineral is felspar; it has different crystalline forms accordingly as it contains lime, potash, or soda.

Igneous Rocks.—There are certain surface rocks that have cooled from a molten condition, and of these the lavas of volcanoes, though not the most abundant, are perhaps the best known. The Hawaiian Islands are mainly great piles or domes of lava, and this kind of rock is common in most mountainous regions. In many instances the molten rock has been ejected from long fissures and has cooled slowly; in this form it is usually known as *basalt*, or, if it breaks into regular blocks, *trap*. The Palisades of the Hudson, Fingal's Cave, and the Giant's Causeway are examples.

All the foregoing are commonly called *volcanic* or *igneous* rocks; consult a good dictionary and learn why these names are applied. Igneous rocks are usually found in mountainous regions, or in localities from which the sedimentary rock has been removed. Granite rocks prevail in the New England Plateau; igneous rocks are abundant in the Western Highlands.

Sedimentary Rocks.—Although the sedimentary rocks that prevail in such a great extent of the land are derived

from the granitic and other vulcanic rocks, there is nothing about them to indicate their close relation to the latter. The making of firm rock out of loose sediments is a somewhat complex process. Let us follow the formation of sandstone. In the first place the grains of quartz are rounded, and in the second place they are uniform in size. The rock from which they came, probably granite, has crumbled, and water has sorted the various minerals from one another. The waves, beating the fragments of quartz and rubbing them against one another, have not only rounded the grains, but they have also sorted them according to size, and piled them in a nearly flat layer. True sand, therefore, is nearly always a formation of beaches or of water in motion.

In time the beach is lifted up above sea-level and covered deep with vegetable remains mixed with loam. Water, in one form or another, flows over or stands upon the surface; and if the water contains lime in solution it will leach through the layer of sand and cement the grains, forming *sandstone*.

In most instances, clay banks are derived from granitic and similar rocks. Felspar decomposes into clay, and the latter, being very light and fine, is carried off by the water, settling by itself, while the heavier materials remain. In many instances the clay is spread over large areas. Possibly it remains in the stiff, pasty form by which it is commonly known; more likely pressure, heat, and moisture, acting together, convert it into *slate*.

It is not difficult to understand how rivers and other running waters are active workers in making rock, because one can almost always find clay-banks, gravel-beds, and other sediments that have been brought down stream and distributed by the water.[11] It is not so easy to understand how rocks are found at the bottom of the sea; as a matter

SEDIMENTARY ROCK, NEAR OLEAN, N. Y.

The face of the cliff is one side of a channel of the river.

of fact, however, probably more sedimentary rock has been formed in ocean and lake beds than in any other places. In very many instances these rocks are largely composed of the remains of animals so small that several thousand of them together would not be so large as the head of a pin.

The sea, especially in regions of warm water, contains many thousand species of such animals; moreover they multiply with great rapidity. But the animals are short-lived, and as soon as they die their bodies sink to the bottom. The mineral remains of these organisms consist mainly of lime or silica, and in time the thick layer that accumulates finally becomes cemented into rock. The growth of rock in this way is slow, it is true, but time alone

is required to make such layers of very great thickness. The chalk cliffs of England and France were formed in this manner, and they aggregate nearly half a mile in thickness. The limestones of the Mississippi Valley also accumulated on sea-bottoms and have about the same thickness.

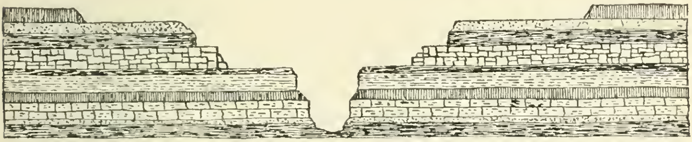
Metamorphic Rocks.—There are many instances in which the character of sedimentary rocks has been subsequently changed. Thus, by pressure and heat in the presence of moisture, beds of clay have been transformed into layers of gritty slate; chalk and limestone have become crystalline marble; and bituminous coal has become anthracite. Certain kinds of granitic rock, especially gneiss or "stratified granite," are metamorphic. Older granitic rock has crumbled, and the rock waste has been cemented into firm rock again with but little alteration.

One might infer, therefore, that the older and deeper stratified rocks would be thus changed.[12] This is usually the case. The weight of the overlying rock produces immense pressure, and the changes resulting from the moisture within them greatly alter their appearance. Many of the older rocks, indeed, are much like igneous rock in appearance. Rocks that form a part of mountain folds are apt to be metamorphic on account of the pressure that results from the folding and crumpling.

EXERCISE.—Procure specimens of clay and slate, chalk (not crayon) and marble, bituminous (soft) coal and anthracite. Examine each pair with reference to hardness, foliation, crystalline appearance, and density (weight of pieces of equal size). Make a list of the rocks occurring in the neighborhood in which you live, and classify them as igneous, sedimentary, or metamorphic.

Order of the Strata.—Most of the sedimentary rocks were deposited in horizontal layers, but, on account of the vertical movements of the rock envelope, they are often

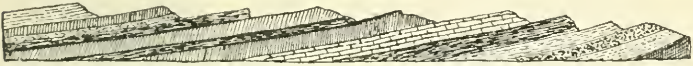
found in oblique positions. Sometimes they occur in gentle folds; but in mountainous regions they are much crumpled and broken. In some of the old sea-beds now raised above the surface the strata are undisturbed.



SEDIMENTARY ROCK: SECTION THROUGH THE CAÑON OF THE COLORADO RIVER

The level of the strata has not been disturbed.

It is by studying the upturned edges of broken and tilted strata that the story of the earth has been read. Each stratum is a chapter by itself, and to read the history properly it is best to begin with the lowest. It is not always easy to tell the relative position of strata at some distance from one another, but as each stratum has *fossils*, or animal remains peculiar to itself, the position is usually determined by the kind and character of these.

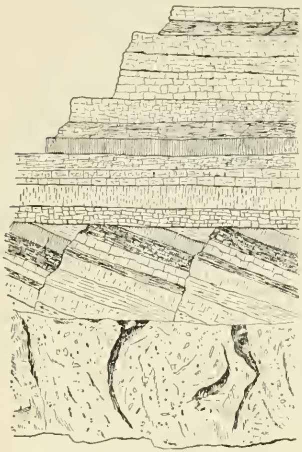


SEDIMENTARY ROCK: TILTED STRATA

The total thickness of the stratified rocks is estimated at upward of twenty miles. There is no locality known, and none exists, in which all the various strata are found—no locality is known in which even any considerable number occur. Not infrequently very old rocks are overlaid by those of the most recent formations; all the intermediate strata are missing.[13]

To the lowest strata, that do not differ much from the granitic rocks and possibly include some of them, the name

Archæan" is given. They seem to be the foundation of the continents and the floor of the oceans. The decay and wearing away of these has formed the material of which nearly all the sedimentary rock is composed. "*The waste of the old land is the material of the new.*"



UNCONFORMABLE STRATA: CAÑON OF THE COLORADO RIVER

The tilted strata, originally horizontal, were deposited on the surface of the igneous rock: Subsequently the upper layers were deposited on the broken surface of the tilted layers.

The remaining strata are named in accordance with the character of the life forms that existed when the rocks that compose them were undergoing formation. Upon the Archæan, rest the rocks of the *Palæozoic* era—the age of the earliest life forms. Then follow the rocks of the *Mesozoic*, or middle-life era; the *Cenozoic*, or era of recent life; and, last of all, the era of man.

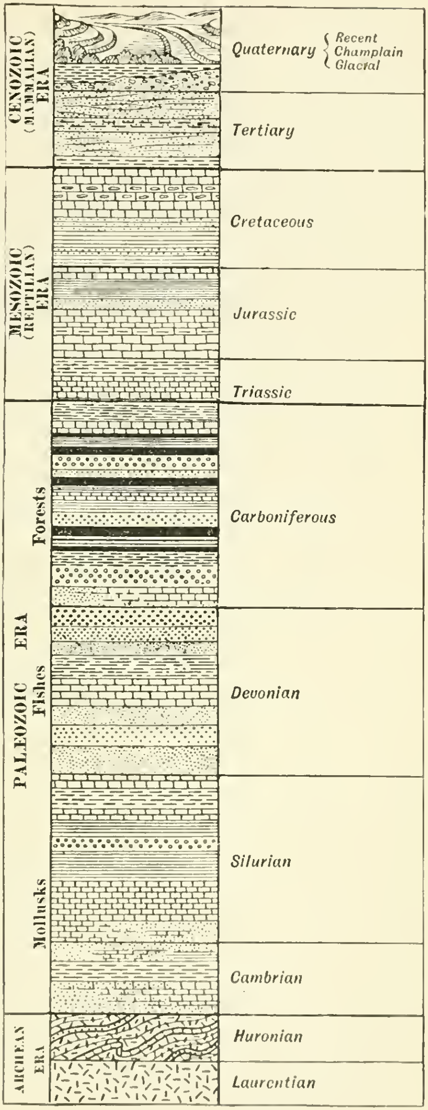
Archæan Era.—In Archæan times North America consisted mainly of a narrow, V-shaped strip of land south of Hudson Bay. The crests of the Appalachian Mountains were just above the sea level ; the Black Hills and one or two peaks of the Rocky Mountains had also just emerged. The general form of the American continent was outlined in Archæan times. With the possible exception of a few species resembling the sponge, no forms of life are found in Archæan rocks. (*See illustration, p.* 34.)

Palæozoic Era.—The Palæozoic era was of very long duration. The sediments composing it are 25,000 feet thick in places. The greater part of Europe and North America were above sea-level during this period, but the

land was many times upheaved and submerged. In North America the greater part of the Mississippi Valley was a shallow inland sea, that later became an immense marsh.

In the variety and extent of life forms the Palæozoic era is the most noteworthy of all the geological periods. It began with the lowest form of sponges and closed with the advent of mammoth reptiles. During this period animals with backbones appeared for the first time. Insects were numerous, and toward the close reptiles existed. Fishes and mollusks seem to have been the prevailing forms.

The climate was warm and moist. The vast accumulations of vegetable matter that are now the coal fields



ORDER OF STRATA

were found in swamps of this age.[15] In North America these swamps covered much of the area that is now the central United States.

Mesozoic Era.—During the Mesozoic era both North America and Europe had grown to about their present shape. In the former division the Gulf of Mexico reached as far north as the mouth of the Ohio, and a northwestern branch of it extended nearly to the 50th parallel. In Europe all the principal mountain ranges[16] and the higher elevations of land most probably had been raised permanently above sea-level.

NORTH AMERICA IN ARCHÆAN TIMES

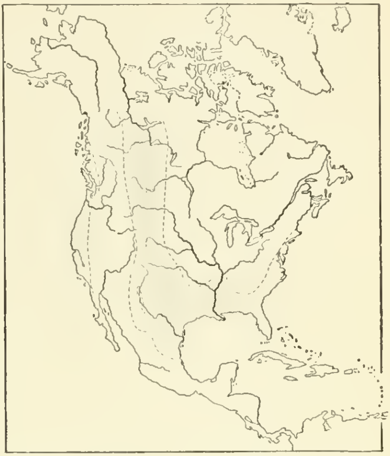
The shaded area shows the part of the continent above sea-level.

It was an age of gigantic reptiles. The animals of some species were from sixty to eighty feet in length. For the first time birds appeared. They were very much like reptiles, however, and in some species they had, instead of horny beaks, heavy jaws with socket teeth.

Cenozoic Era.—This era was largely one of uplift and mountain-making, although both in North America and Europe the various ranges and systems had received definite forms. The former was a continent of vast fresh-water lakes; the latter of inland seas.

Most of the life forms that flourished in preceding ages were common, but one great step in advance may be noted—the appearance of mammals. Their genera included

the elephant, camel,[17] rhinoceros, wolf, deer, and horse.[18] There was a considerable advance in plant-life, and the forest trees both of North America and Europe included most of the species found to-day.



NORTH AMERICA IN CENOZOIC TIMES

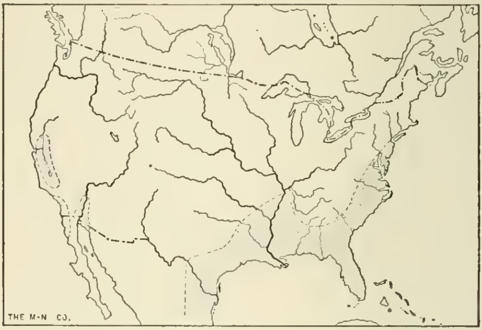
The unshaded area shows the part of the continent above sea-level.

Quaternary Age. — The abrupt close of the Cenozoic era was probably due to an elevation of a large part of North America and Europe from 1,000 to 2,000 feet, and a decided lowering of temperature. The ice and snow of the north polar regions crept southward until it enveloped nearly all of Europe and the greater part of the United States. This accession of ice is commonly known as the *glacial epoch.* It is marked on a stupendous scale by a movement of drift similar to that which marks the glaciers of the present time.

The changes of the Quaternary age were disastrous to life. In the area covered by glacial ice most of the species of larger mammals perished. The cave bear, horse, wolf, and reindeer survived. Many species of plants were destroyed, but many escaped.

That man existed before the close of the glacial epoch seems certain. In the caverns of Belgium, Germany, and Italy the bones of man have been found in caves along with the skeletons of animals and various implements of the chase. From the few scraps of unwritten history it

seems that primitive man was a savage of the lowest type. He lived in caves and obtained his food by hunting and fishing. He did not cultivate the soil nor did he have any



THE UNITED STATES AT THE BEGINNING OF THE QUATERNARY AGE

The shaded area shows the part added in recent times.

domestic animals. He had learned the use of fire, however, and from that moment his intellectual development was a question of time only.

QUESTIONS AND EXERCISES.—A mixture of iron filings, sand, and meal is gently shaken in a glass: what position will the components take when they come to rest? Explain why.

It is sometimes assumed that the rock envelope is about forty miles, and the atmosphere about two hundred miles, in thickness. Construct a diagram on the blackboard or on paper, showing the relative thickness of each on scale in the ratio of 4000 : 40 : 200.

Obtain specimens of iron ore, marble, and dry clay, and compare the weight of pieces of the same size. If possible find the specific gravity of each. Determine, or judge by "hefting," the relative weight of the various kinds of rock in the neighborhood in which you live.

Note and describe any instances within your personal knowledge of the action of water on the rock envelope; explain the nature of the changes and how they have been brought about.

Study the various rock formations in the neighborhood in which you live and classify them according to their origin—that is, as sedimentary or igneous.

Make a collection of them for future use.

A stream flows over a bed of limestone rock that is slightly soluble, into a lake without an outlet; what changes in the formation of rock are likely to occur? Will the rock formed be stratified or unstratified? In what way may it become fossiliferous?

From the official State reports find the order and distribution of rock strata in the State in which you live, and from the information given construct a geological map.

COLLATERAL READING

POWELL.—Physiography of the United States, pp. 22–29.
LE CONTE.—Elements of Geology, pp. 127–132.
MILL.—Realm of Nature, pp. 211–230, 249–261.
SHALER.—First Book of Geology, pp. 107–124.

NOTES

[1] That is, the substances specifically heaviest are nearest, and the lightest are farthest, from the centre.

[2] Iron and its compounds form one of the most abundant constituents of the earth, and it is likewise one of the most abundant substances of the sun and of some of the fixed stars. All the meteorites that have landed on the earth contain it, and in most of them it is the chief element present.

[3] It must not be inferred from this, however, that the heated interior is in a *liquid* condition; on the contrary, the earth behaves like a solid but somewhat elastic body. The melting or fusing of a substance depends not on temperature alone, but on pressure as well. With increase of pressure, the temperature of fusion is also raised; and the great weight of the overlying rock may possibly produce a pressure great enough to prevent liquefaction.

[4] The increase varies not only in different localities, but in different kinds of rock, the average being one degree for each sixty or seventy feet. In a certain boring in Upper Silesia, 6,700 feet deep, there is a slight decrease in the ratio, but a marked increase in the actual temperature at the greater depths.

[5] The crystalline form of many rocks is due to the water they contain in chemical combination, and there are but few rocks of

which water does not form a considerable part. It is by no means impossible that the waters of the earth, in time, may be absorbed in this way, disappearing as free water, to reappear in chemical combination.

[6] About one-fifth of the atmosphere consists of free oxygen, an element that forms also about one-half the weight of the earth's crust, so far as can be estimated. In time, possibly, all the free oxygen will be absorbed, entering into chemical combination with other substances.

[7] In most instances the rate of sinking is about equal to the depth of the layer of sediment annually spread over the surface. The amount of sediment carried into the Gulf of Mexico is enormous, but it does not apparently raise the level to any great extent ; few parts of the made-land surrounding the gulf are more than ten or fifteen feet above sea-level.

[8] At San Pedro. California, the upward movement has been unusually rapid. Several layers of shells mixed with sand are found one above another, at heights varying from five to fifteen feet or more. The shells belong to species some of which are not now extinct, and most of them have been preserved in their natural state. The highest beach is nearly three hundred feet above sea-level. The various beaches are so slightly weathered that they seem scarcely altered. *(See illustration, p. 24.)*

[9] According to this principle the rock envelope of the earth always maintains a state of balance, adjusting itself to the load it carries. It is readily illustrated by putting an ounce weight on an inflated toy balloon. The surface of the balloon is depressed by the weight, but if the latter be removed the surface again rises ; or if the weight be moved from one part of the balloon to another the surface at the one part rises while at the other it sinks.

[10] Normally, granite is a mixture of mica, felspar, and quartz. If it contains hornblende instead of mica it is called *syenite ;* if both mica and hornblende are present it is *syenitic granite.* If the felspar contains soda the granite is *diorite.* If the rock shows layers it is then called *gneiss.*

[11] An interesting example of rock-formation occurs at Sweyney Cliffs, Shropshire, England. A small stream of water pours over a red sandstone cliff, mainly in the form of a rapid. The water contains a considerable proportion of lime and magnesia ; and a

species of coarse moss grows freely in the saturated earth about the stream-bed. The mineral salts of the water are deposited copiously on the moss, and little by little the latter, together with the other matter entangled, has become so completely incrusted that it forms a dyke about twenty feet wide. The dyke stands out, having built itself from the edge of the cliff a distance of ten feet or more. About three cubic yards are added each year.

[12] Substances ordinarily insoluble in water are quickly changed when subjected to water under a high temperature. If a thick steel tube, filled with water and fragments of granite, be intensely heated for several hours, the larger part of the rock will be dissolved. Hot alkaline water will also dissolve granitic rocks, the dissolved matter being precipitated when the water cools.

[13] Thus, the rocks of the Mississippi basin belong to a very old and remote geological period. They are overlaid by a thin cover of rock waste that belongs chiefly to the most recent period.

[14] The word *Archæan* means "the beginning"; *Palæozoic* is derived from two Greek words meaning "early life"; *Mesozoic*, similarly, is "middle life"; and *Cenozoic*, "recent life." The Silurian age was named from "Silures," a former name for the people of Wales; *Devonian* comes from "Devon," England; *Huronian*, from "Huron"; and *Laurentian* from "St. Lawrence." All these names are derived from the localities in which the rocks were first studied.

[15] Coal measures are not confined to the Carboniferous age; they occur in all geological ages. Thus, the coal fields of the Pacific coast belong to the Tertiary age. Those of the Carboniferous age, however, are so vast in extent that they overshadow all other features.

[16] The uplift of the Pyrenees Mountains did not occur until nearly the end of Mesozoic times.

[17] There were several species of camel during these times. It is interesting to note that this animal, now confined to the eastern continent, was a native of the west.

[18] The earliest species of horse had, instead of one, five toes. In subsequent times two of these gradually disappeared. The horse of modern geological times has but one toe, but the "splint bones" just above the hoof are the toes of the Quaternary horse.

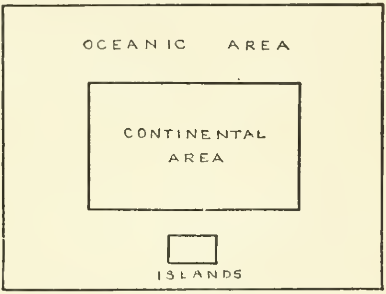
WATER HEMISPHERE

LAND HEMISPHERE

CHAPTER III

LAND AND WATER, AND THEIR OUTLINES

THE surface of the rock envelope is not smooth, nor is any considerable part of it perfectly level, as the word is commonly used. More than three-fourths of its surface is covered by the sea, but the remaining part consists of very irregular areas that are higher than the level of the water. The great body of water that covers so much of the rock envelope is the *sea;*[1] the areas above sea-level constitute the *land*. The lowest part of the rock envelope below sea-level—that is, the lowest part of the sea-bottom—is about five and one-half miles, and the highest point above it is just about the same distance. The average elevation of the land is not far from 2,000 feet, but the average depth of the sea is about 2,000 fathoms.



RELATIVE AREAS OF LAND AND WATER

The land aggregates about 53,000,000 square miles. It clusters around the north pole, and from this circumpolar region it radiates toward Cape Horn, toward the Cape of Good Hope, and toward Tasmania. In which hemisphere is the greater part? Which of the two temperate

zones includes the greater area? How many great land masses, each surrounded by water, are there? The two largest masses are divided nearly in twain, each at the central part,[2] and the smallest is separated by an arm of the sea which seems to have severed it from the largest. The three largest land masses are called *continents*;[3] the smaller ones *islands*. The line along which the land and the sea meet is the shore; the narrow strip of land next the shore, the *coast*.

The Continents.—The continents are so called on account of certain features of their structure. Each one, for convenience, is divided into *grand divisions*, and the latter

RELATIVE AREAS OF THE CONTINENTS AND GRAND DIVISIONS

are also conveniently called continents. In general, the continents have a high border on one side and a lower one on the opposite side. They are variously named, but they are usually styled the Eastern, or Asian; the Western, or American; and the Australian. The shore of a great body of land in the south circumpolar regions is known to exist, but practically nothing is known of its extent.

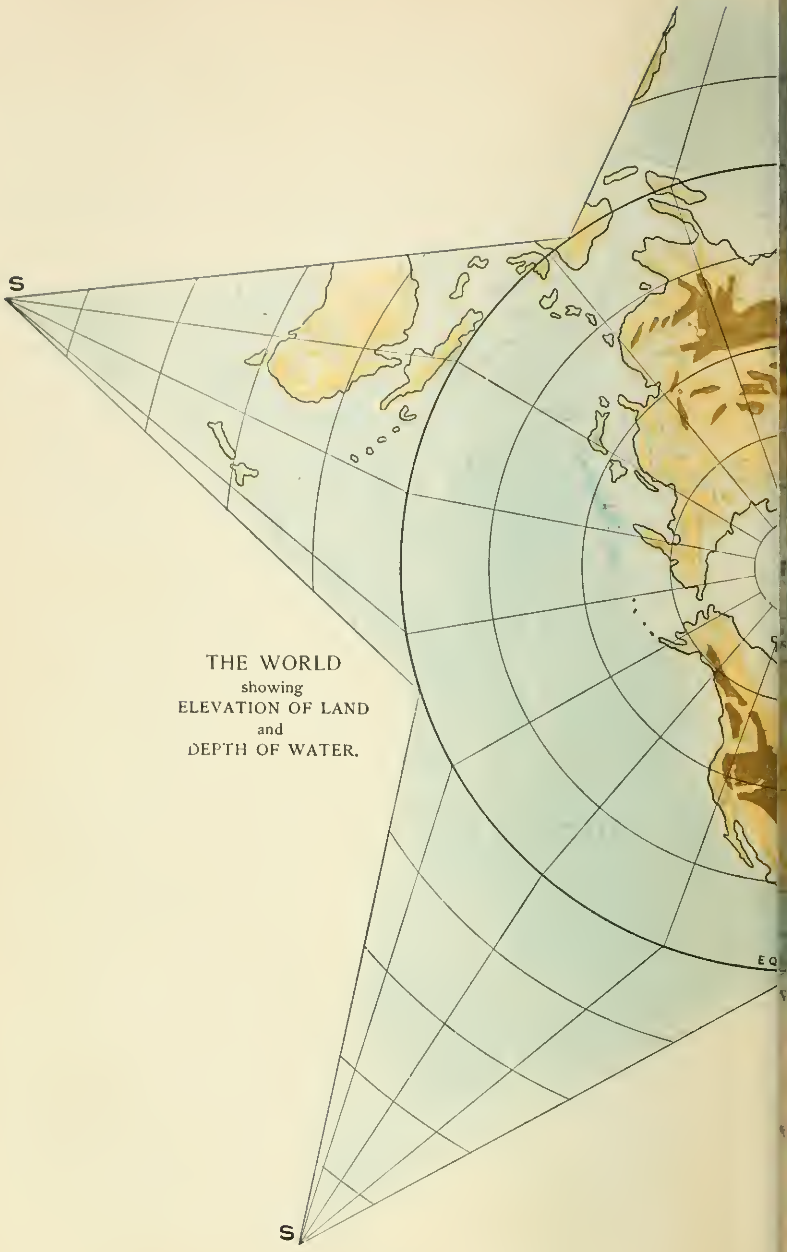
In a previous chapter it has been noted that changes in elevation, especially along the shore, are taking place. The real extent of the continents, therefore, is not apparent; in many places it comprises an area somewhat greater than the part above water. Each is surrounded by a margin, varying from a few rods to one hundred miles or more, upon which the sea is comparatively shallow; be-

yond this margin the surface slopes rather abruptly into deep water.

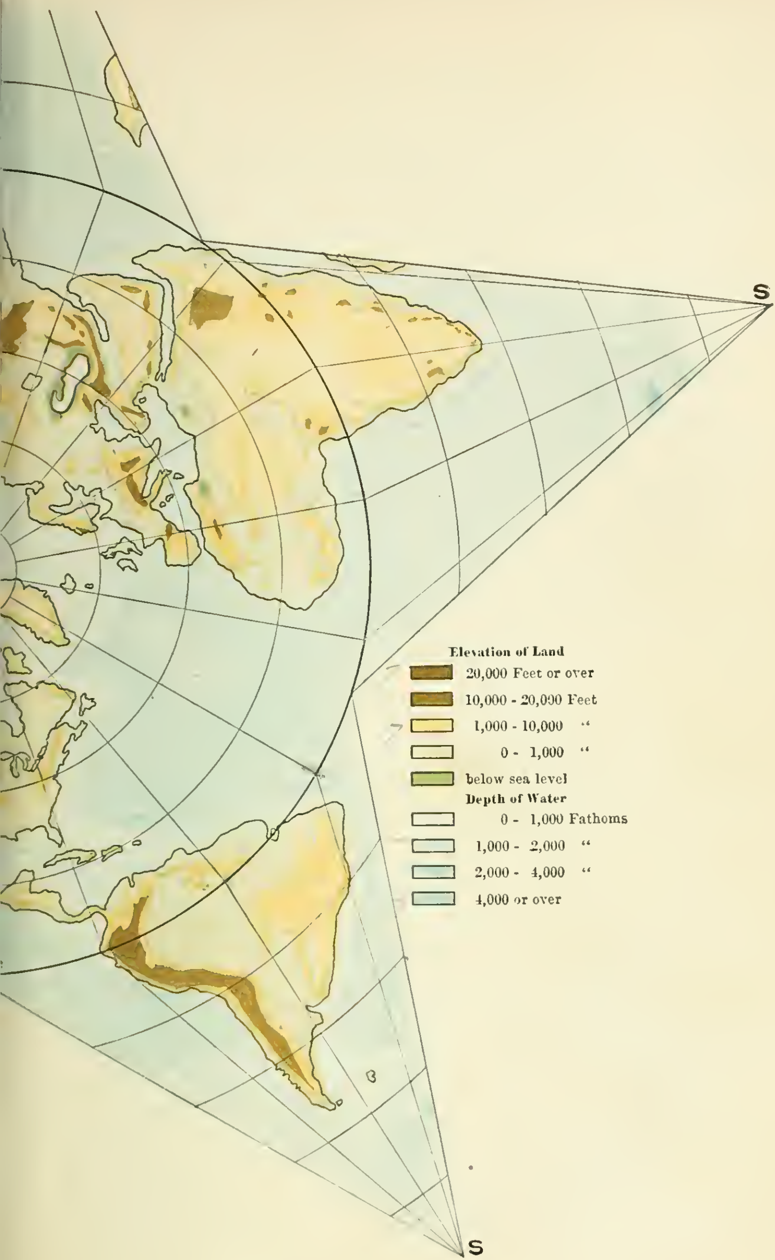
The submerged margin is very generally considered a part of the continent. The depth of water along its extent varies, and in places the margin itself reaches above sea-level. The margin of each continent is more or less continuous, and forms a high surface in comparison with the surrounding sea-bottom. It is usually called the *continental shelf*.[1] The map on p. 45 shows both the highland and the lowland regions of each continent and also its submerged shelf: facing what ocean are the highlands?—the lowlands? Where is the continental shelf widest?—on which side of North America has it the greatest width? The highlands are represented by the area above the level of 2,000 feet: compare the extent of highlands and lowlands in each continent; in North America. Are the highlands continuous or broken? Each one is a great plateau rimmed and traversed by lofty mountains. About one-fifth of the Australian, two-fifths of the American, and three-fifths of the Asian continent are above the 2,000-foot contour.

The altitude of the highest regions of the continents differs much. The greater elevations of North America are from one to one and a half miles above sea-level; those of South America, about two miles; and the highest parts of Asia are more than three miles above sea-level. The mountains that rim or surmount the highlands are much higher—in many instances about twice as high.

The slopes toward the Arctic and Atlantic Oceans are long and gentle; how does this fact compare with the slopes of the Pacific and Indian Oceans? As a rule, the lowland regions are more nearly level than the highlands. On which side of the eastern continent are its principal lowlands? On which side of the American continent are they situated?

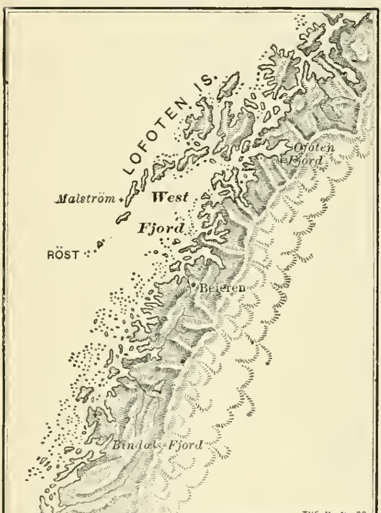


THE WORLD
showing
ELEVATION OF LAND
and
DEPTH OF WATER.


S
S
Elevation of Land
20,000 Feet or over
10,000 - 20,000 Feet
1,000 - 10,000 "
0 - 1,000 "
below sea level
Depth of Water
0 - 1,000 Fathoms
1,000 - 2,000 "
2,000 - 4,000 "
4,000 or over

The mean elevation of the land varies considerably in the various continents. If their surfaces were levelled off Australia and Europe would be not far from one thousand feet high; North America and Africa about two thousand feet; and Asia nearly three thousand feet. Africa would be probably a little higher, and South America not quite so high as North America.

In a few instances there are depressions in the land below sea-level. The surface of the Caspian Sea is eighty-four feet below that of the Mediterranean; the Dead Sea, situated in a gash north of the Red Sea, is thirteen hundred feet below sea-level. There are two small depressions in North America, north of the Gulf of California; and two or three in Africa, south of the Atlas Mountains. It is not unlikely that these were former arms of the sea that were severed from the main body.



A STRETCH OF THE COAST OF NORWAY

The coast, deeply indented with fjords, is bordered by many thousand rocky islets.

Islands.—The islands have an aggregate area of about three million square miles, or about one-seventeenth of the entire land surface of the earth. The majority of them are situated on the continental plateau, and are at no great distance from the continents to which they belong. Many of them are partly submerged ranges of mountains that are parallel to the maritime ranges of the continent, or that extend from it. Find two

such chains near the American continent, two near the Asian continent. Islands of this character are usually called *continental islands*; and the reason is obvious.

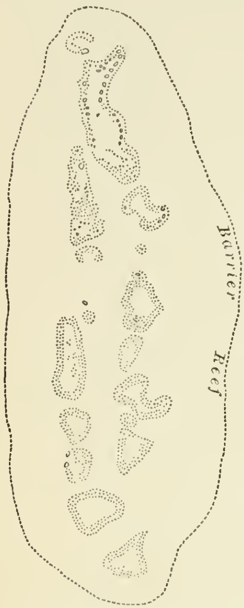
In a few instances, here and there, are islands far distant from any large body of land. There is no doubt about the origin of some of them; they consist of the lava that has been ejected from volcanoes. In some instances these islands are solitary, as Jan Mayen and St. Helena; in others they form a chain, as the Hawaiian group.

In the Pacific Ocean there is a large area in which islands are so numerous that they form the well-defined grand division Polynesia; find the meaning of this word from the dictionary. These islands occur in quite regular chains that are roughly parallel in direction; they are therefore thought to be the higher summits of submerged mountain-ranges. In some instances a volcanic peak is in sight, but for the greater part the position of each peak is marked by the reef of coral growth that encircles it. The islands themselves are popularly known as *coral islands*.[5]

It has been inferred that the coral polyps began their growths on the slopes of the volcanic peaks, and that the latter gradually subsided until they were covered by the sea. But while the peak was slowly sinking the coral polyps steadily built their reefs upward, keeping the top always even with the wash of the waves. This opinion, first made prominent by Darwin, is borne out by the fact that, while the coral polyp cannot live more than twenty fathoms below the surface of the sea, the reefs sometimes extend almost vertically to a depth of several hundred fathoms.

A peculiar feature about many of these islands is their form. As a rule each consists of an irregular ring of reef matter, broken and tossed up by the waves, surrounding shallow water. The reef is called an *atoll*; the enclosed

water a *lagoon*. Usually the atoll is broken in one or more places, and in many instances the lagoons form good harbors. The reef is rarely more than a few feet high, and its vegetation is confined to a few species, mainly of palms.



A GROUP OF CORAL ATOLLS SURROUNDED BY A BARRIER REEF

The Sea.—The sea covers more than half the northern and about seven-eighths of the southern hemisphere. Although the area it covers is continuous, it is separated by the continents into great divisions called *oceans*. Name them. Which one is nearly enclosed? Compare the Atlantic in shape with the others. For convenience, the polar circles are taken as the boundaries of the polar oceans, and the equator conventionally divides the two largest oceans into northern and southern divisions. Which of the oceans is nearly landlocked? At what place do the Pacific and Arctic Oceans meet? the Atlantic and Pacific? the Atlantic and Indian? the Atlantic and Arctic?

The Pacific Ocean comprises about one-half the entire Sea; the Atlantic about one-quarter. The shore line of the latter, however, is considerably longer; explain why. Why are not the polar oceans important routes of traffic? On a globe trace a northwest passage from London to India; why is not such a passage feasible as a trade route?

In general, the average depth of the oceans varies with their size—the larger the ocean the greater its depth. The Pacific is about 2,500 fathoms, the Atlantic and Indian not far from 2,000 fathoms. The polar oceans are shallower,

but not enough is known about their depth upon which an average can be computed. The greatest ocean depths are much in excess of the average depths. There is a large 3,000-fathom area in the north Pacific—compare it with Australia in size—and several smaller areas in the Atlantic and Indian Oceans. There are also several 4,000-fathom and at least two small 5,000-fathom areas; describe their positions.[6] The greatest depth of the sea, it is seen, scarcely surpasses the height of the loftiest mountain peak; yet while four-fifths of the sea basin is six thousand feet lower than sea-level, less than a tenth of the land reaches six thousand feet above it.

The floor or bed of the sea is by no means so irregular as the surface of the land; and, the vicinity of the coral islands and the continental shores excepted, no steep slopes or abrupt changes of level are known to exist. The soundings made for the telegraph cables disclosed no slopes nor inclines too steep for a railway grade. After deep water was reached, the soundings for the Atlantic cable of 1866 did not vary more than seven or eight hundred feet in two thousand miles.

Arms of the Sea.—In various places the sea extends to a considerable distance within the general outlines of the continents, forming the bodies or arms called seas, gulfs, bays, sounds, straits, etc. Many of the smaller coves and estuaries are shore formations, having been made or shaped by the action of waves or by currents of water. The larger arms, however, are structural, and have resulted from upheaval or depression of the continent, or of some part of it.

The borders of a continent may be flanked by lofty highlands, and the trend of the coast usually conforms to the trend of the ranges. Thus, the bend that gives the west coast of Africa its shape also gives a similar form to

the Gulf of Guinea. Where parallel ranges extena seaward, or form an angle with the coast, the sea usually enters the valley to some distance between them. On a map of North America, note the position of the Gulf of California, and Puget Sound; on a map of Europe, the Adriatic Sea. Note similar examples along the west coast of Asia. Compare the coast lines of the grand divisions with reference to indentations. Which has the longer coast line—Europe or Africa?

A ROCK-BOUND COAST: THE CYCLOPS, COAST OF SICILY

Unfit for commerce and a menace to navigation.

Almost any partly enclosed portion of an ocean is called a sea, and the Caribbean and North Seas are examples of a type of enclosed waters. There is another type, however, that is even more remarkable because practically land-locked. Of this type the Mediterranean is an example, and such arms of the ocean are now often called *mediterraneans.* The Gulf of Mexico is properly included in this class. Nearly all the larger arms of the sea are de-

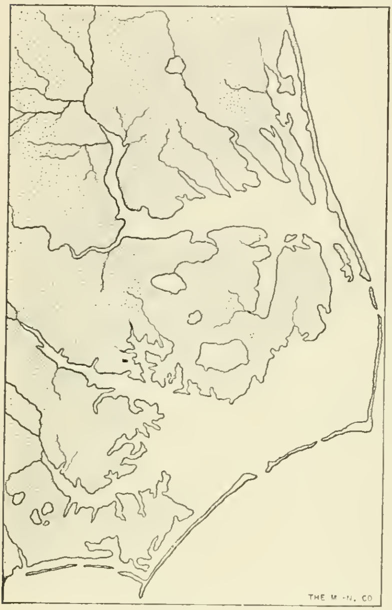
pressed parts of the continents, or of the plateau on which they are situated.

Coast Forms.—The study of almost any good map of a continent, or of any considerable part of its shore outlines, shows that various parts of the coast differ materially. Compare, for instance, the coasts of Maine and Florida; of the Chesapeake Bay and southern California. The illustrations on pp. 46 and 52 are examples of shore forms. One of them is a rock-bound coast deeply indented with fjords and hemmed in by rocky islets. This coast has been worn and frayed by the action of sheets of ice, but it has also subsided until the valleys are submerged by the sea. Name the various coasts that resemble it.

A CLIFF-GIRT COAST, SAN JUAN, PUERTO RICO

In the illustration on p. 52, the plain bordering the sea dips so gently below sea-level that the water is shallow half a mile or more from the shore. The drag of the waves rolling in and combing on the coast picks up sand and rock waste brought down by muddy streams and piles it in the form of long spits and beaches at a little distance from the shore.[7] Find other coasts that resemble it.

Along many parts of the coast the sea seems to be encroaching on the land, and the waves beat against the shore, breaking it away until there is a high cliff with a narrow beach at its foot. A considerable extent of the California coast is bordered by sea-cliffs, and they occur here and there along the North Atlantic coast, as at the coast of Newport, Rhode Island.



A STRETCH OF NORTH CAROLINA COAST

The barrier beaches nearly enclose the coast; the inlets are kept deep enough for navigation by the tidal currents.

Coral formations are very important factors in shore lines. On shore they are called *fringing reefs*; farther out, *barrier reefs*. Almost the entire east coast of Australia is shut off from open communication by a barrier reef more than twelve hundred miles long. There are a few channels across the reef, but the latter is a great obstacle to commerce. Fringing reefs occur on the south coast of Florida, and they are perhaps the most common examples of coral formation. They are common along the shores of the Bahama Islands, and occur here and there along the Hawaiian coast.

Coral growths are confined to warm, littoral waters, and the reef-building polyp is limited to waters whose temperature does not fall below 25° (67° F.). Absolutely clear

water is requisite, and for this reason coral reefs are rarely found along the shores of continents, and never within the reach of river sediments.

Coast Outlines and Civilization.—The coast forms of a country have not a little bearing on its prosperity and its enlightenment as well. A coast with good harbors invites commerce and intercommunication. Along the North Atlantic coast of the United States, where a rugged surface slopes abruptly below sea-level, good harbors are numerous. The same conditions prevail on the coast of Europe. Of two regions, one having good, the other poor harbors, commerce and intercommunication will seek the former. Africa and South America have but very few good harbors, and to this fact the half-savage condition of the native peoples is largely due. The great stride in the progress of the Japanese people was begun when they opened their ports to foreign trade.

QUESTIONS AND EXERCISES.—How have good harbors affected the progress of the English people? What has been the effect of closed ports on the Chinese?

Compare the commerce of the North Atlantic coast of the United States with that of the South Atlantic coast. To which type does each of these coast forms belong? Where are most of the large seaports of the Atlantic coast of the United States? Explain the reason for their location.

Why should Australia be considered a continent rather than an island?

Does the cutting of the Suez Canal give Africa any insular properties that it did not possess before?

Make a list of the principal mediterranean seas of the world.

Mention several instances in which peninsulas enclose waters so as to form gulfs or bays.

From a good map of the British Isles find the names used as synonymes of "cape" and "strait."

Find the centre of each hemisphere on p. 40.

Study the position of the submerged part of the continents on the map, pp. 45-46.

COLLATERAL READING

DANA.—Manual of Geology, pp. 145–152.

REDWAY.—New Basis of Geography. *Chapter IV.*

SHALER.—Sea and Land, pp. 187–222.

UNITED STATES GEOLOGICAL SURVEY.—Norwich and New London Sheet (drowned valleys); Sandy Hook and Barnegat Sheets (spits and barrier beaches); Port Washington Sheet (cliffs).

NOTES

[1] It is commonly asserted that the same amount of water exists on the earth at the present time as during remote geological periods. This is doubtless true, but it is also true that not all the water is in the same form now as in prior times. When the earth was younger there was much water in a liquid form that is now chemically combined with various mineral elements. Nearly all the minerals, especially those in a crystalline form, contain notable proportions of water in combination.

[2] This separation of the land masses has been aptly called the "zone of fracture." The isthmus of Panama is scarcely thirty miles wide and the isthmus of Suez is only one hundred miles across. Yet these two necks of land are all that connect the divisions of each continent. That is, twenty-five thousand miles of open navigation are obstructed by less than one hundred and thirty miles of land. Even these barriers are disappearing because of canals either completed or projected.

[3] It is now the custom to restrict the latter term to the largest land masses, but it is sometimes more convenient to apply it to a grand division. Europe and Asia are also called continents, but the only real boundary that separates them is the desert highland that separates western from oriental civilization. Physically it is better to treat Eurasia as a whole—politically and historically the two divisions are best considered separately.

[4] This margin is also called the *continental plateau*, the *continental border*, and the *submerged border*.

[5] The coral polyp is a zoophyte form of marine animal growth not unlike a tree with its branches. The mouths of the polyp

completely cover its upper surface in much the same manner as the flowers of the hollyhock or mullein cluster about the stem. In a single community the growth of the polyp is chiefly upward, but where the communities are thickly clustered, their branches interlock and finally form a compact mass. The living portion of a coral is found at the surface of the water or a few feet below it ; the dead portion may extend a hundred fathoms or more below the surface.

[6] The deepest soundings so far obtained are 4,655 fathoms by the U. S. S. *Tuscarora*, east of Japan, in an area now known as Tuscarora Deep ; 5,147 fathoms, one hundred miles E. N. E. of Sunday Island ; and 5,155 fathoms a few leagues east of Macarthy Island, not far from the Kermadec group. The two last were made by Commander Balfour, H. M. S. *Penguin*. North of Puerto Rico a sounding of 4,651 fathoms has been obtained. The cable ship *Nero* reported a sounding of 5,200 fathoms east of the Hawaiian Islands. Formerly deep sea soundings were made with heavy Manila rope, and in very deep water it was impossible to tell when the sinker had reached bottom. With the method perfected by Admiral Belknap and Captain Sigsbee, steel piano wire takes the place of the rope. The wire carries at its lower end a sinker which detaches itself on touching bottom, at the same time closing a cup that secures a specimen of the bottom. Very few of the deep-sea soundings made prior to 1870 are now considered trustworthy.

[7] Marine currents frequently attempt to carry away the rock waste piled up by the waves, and between the two it is dragged into a curved form making a *hook*. Sandy Hook, New Jersey, is an example, and similar examples are found along the shores of Marthas Vineyard and Nantucket.

CHAPTER IV

THE RESULTS OF SLOW MOVEMENTS OF THE ROCK ENVELOPE: PLAINS, PLATEAUS, AND MOUNTAINS

THE larger vertical forms of the land are the results of the slow movements of the rock envelope. Any considerable area of land but little higher than sea-level is called a *plain;* if considerably higher, a *plateau;* if wrinkled, folded, and broken, a *mountain system.* There is no fixed elevation at which an area ceases to be a lowland, or *vice versa*, but in general, surfaces more than two thousand feet above sea-level are called highlands, while those of less altitude are lowlands.

As a rule, the various features that constitute topography are distinct one from another; but in many instances lowlands gradually increase in altitude and become highlands; an almost imperceptible swell in a level plain may develop into a cliff or a ridge; and a mountain-range, little by little, may lose its characteristic form among other features of the landscape. So it often happens that a single topographic form may have the character of several kinds of relief.

Plains.—Any level or nearly level stretch of land is commonly called a plain. Most plains are lowlands, but in a few instances the name is applied to surfaces that are more than six thousand feet above sea-level—an elevation considerably greater than that of some mountain-ranges. The plain east of the Rocky Mountains is an example;

it is higher than the crests of the Appalachian Mountains, and about as high as the highest peaks.

Plains are variously named. The grassy plains of the New World were named *savannas* by the Spanish, and *prairies* by the French—both of which names are very commonly employed. In South America the vast plains of Argentina are called *pampas ;* the grassy plains of the Orinoco, *llaños ;* and the forest-covered plains of the Ama-

A ROLLING PLAIN, VIRGINIA

The forestry is deficient, and the soil only moderately fertile.

zon, *silvas.*[1] In Eurasia, the vast plains that almost girdle the Arctic Ocean are known as *steppes*, their frozen, swampy coast fringe being known as *tundras*. In England and Scotland the terms, *meadow*, *heath*, and *moor*, are used.

Origin of Plains.—Most plains have been formed by the action of water, or have received their surface configuration by it. If shaped by comparatively still water they

are known as *marine* or *lacustrine* plains; the former being old sea-bottoms; the latter lake basins. If formed of sediments deposited by running streams they are *alluvial* plains; if levelled off by moving ice, *diluvial* plains; if on the margin of the sea or a lake, *coast* plains.

Marine and lacustrine plains constitute by far the greater area of the lowland surface of the earth. Originally old sea or lake bottoms, their surfaces are level, because the sediments forming them were deposited in still water. In some instances the floor was filled and levelled off by the remains of minute animals; in others by dead and decaying vegetation.

In time these old bottoms were raised above water-level and, if their surfaces were not wrinkled and folded, they constitute the plains of to-day. Thus, the larger part of the Great Central Plain of North America is an old sea-bottom, and so, too, is most of the great northern plain of Eurasia. Of lacustrine plains, one of the finest examples is the valley of Red River of the North. This plain resulted from the draining of a lake, and was so recently formed that its surface has scarcely been notched by the river that now imperfectly drains it.

The plain surrounding the Caspian Sea is an excellent example of a plain in the process of formation. On the northern side, the gradual shrinkage of the lake has left a plain more than two hundred miles wide, and when at length the lake disappears, a broad, wind-swept plain will take its place.[2] The valley or basin of Great Salt Lake possibly is passing through a similar period of growth and development.

Alluvial plains are usually best developed along the lower courses of rivers, although they exist in narrow reaches along almost the entire length of the stream. The bottom-lands of the lower Mississippi and the Danube;

the mazy deltas of the Nile and the Ganges-Brahmaputra, and the broad, fertile plains of the Po are examples.[3] Name other illustrations.

The surface of a coast plain is made level by the action of the waves, and if an uplift of the surface is taking place, the plain gets gradually wider and wider as successive portions of the sea-bottom are brought to the surface. The coast plain along the South Atlantic and Gulf coast is an

A LEVEL PLAIN, KENTUCKY

A very fertile prairie with considerable forest growth.

excellent example.[1] Much of the material of which it is composed is sediment brought down by the rivers, but the waves have been the chief agent in building it. Throughout its whole extent it is but little higher than tide-water. The line along which the coast plain joins the older land is marked by a rather abrupt slope called the "Fall Line," and in most places the line where they meet is quite distinct.

Most of the rivers are navigable to the Fall Line, and along the eastern side coast a line of cities marks the junction.

Almost every body of land is surrounded by a coast plain; indeed its formation and growth necessarily follows the denudation or wasting of the land. Rock waste is constantly being carried to sea-level by running waters, but beyond this point it can go little or no farther; so it is distributed along the shore and levelled off by the waves. In most instances slow, vertical movements of the rock envelope are concerned in the formation and development of coast plains, but in many cases rivers, waves, and tidal currents divide the work among themselves.

In various places surfaces formerly rugged have been levelled off by the action of the sheet of ice that once covered portions of Europe and North America. Much of the northern part of the United States received the configuration of its surface by this process; the moving sheet of ice scoured off the rugged parts and filled the depressions with the material removed.[5]

Distribution of Plains.—Alluvial and lacustrine plains, of course, are incidents in the physiography of rivers and lakes; and coast plains are formed on nearly all shores. The great marine plains of the world are mainly on the slopes of the Arctic and the Atlantic Ocean. The most extensive plain of the world is that which forms the northern slope of Eurasia. From east to west it stretches a distance of about nine thousand miles; from north to south, about three thousand miles. In Asia it is high and rolling; in Europe the greater part of its extent, however, is low and comparatively level.[6]

In the New World the great continental plain extends from the Arctic Ocean to the Gulf of Mexico, and there is an apparent extension from the Caribbean Sea southward through South America. Its continuity is broken by

occasional ranges and arms of the sea. It presents certain marked contrasts to the plain of the Asian Continent. The latter extends east and west; the former, north and south. The latter is a margin of the continent; the former is an interior plain, bordered by mountain-ranges.

Physiographic Aspect of Plains.—Although water is the chief agent in the formation of plains, it is likewise the chief factor in their destruction. From the moment a plain comes into existence, storm waters and running streams begin to carve channels in its surface. These, extending in area, carry the greater part—perhaps all the surface material away.[7] A plain thus channelled is said to be "dissected." The coast plain of much of the South Atlantic and Gulf coast is young, especially near the sea. Its slope is so gentle that the streams have not yet carved their channels to any great depth.

The plains bordering Lakes Erie and Ontario show signs of greater age. The streams have accomplished a considerable dissection and the channels are comparatively deep. The "Bad Lands" of South Dakota and Nebraska are remnants of an old lacustrine plain that has been so greatly dissected that the region is well-nigh impassable throughout much of its extent.

Economic Value of Plains.—Because of their comparatively level surface, plains are more accessible to commerce than mountainous regions. Railways can be built across them at the minimum of cost, and the rivers that traverse them are usually navigable.

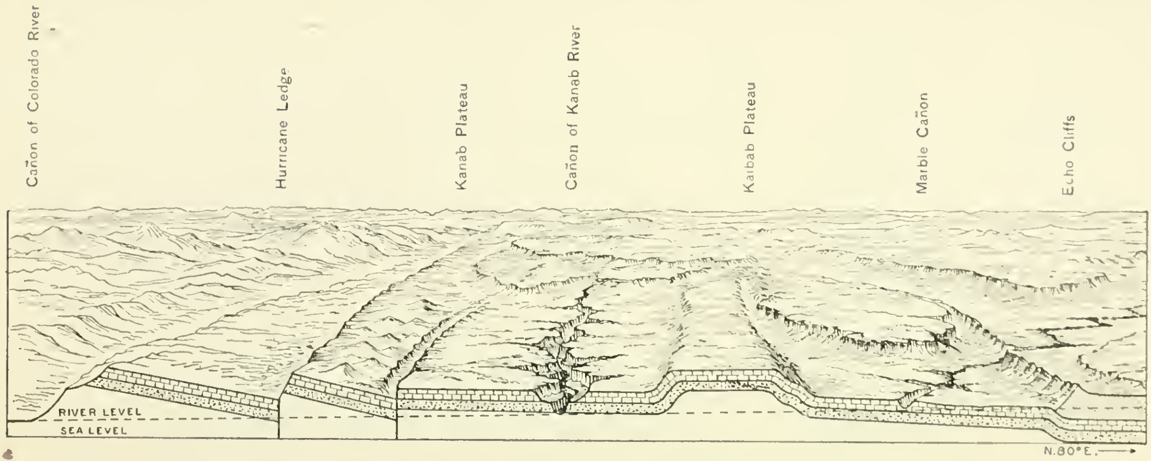
More than this, the soil of plains is usually deep and easily cultivated. Therefore they are capable of supporting a denser population than mountainous regions. In remote times the alluvial plains of the Nile and of Mesopotamia were the seats of dense population and vast industries. In later times the plains of Europe and of the

United States have become the great producers of wealth. It may be said, therefore, that the greater part of the world's wealth and power is centred in the plains of the temperate zones. Only a small fraction of the world's population lives above the altitude of 2,000 feet, and but few of the great cities are more than six hundred feet above sea-level.

Plateaus.—Almost any broad extent of country having an elevation of more than a few hundred feet, and an irregular or dissected [8] surface, is popularly called a plateau. The name, originally meaning "flat," or "level," has acquired a signification almost the opposite. A plateau of small area is usually called a *mesa*, a *table-land*, or a *table-mountain*, according to its general form and structure.

Like most other elevations of the earth's surface, plateaus are the result of a gradual uplift of parts of the rock envelope. Most of the great plateaus of the earth are rimmed by lofty mountain-ranges, and their surfaces are generally traversed by ridges and valleys. Thus, the plateau region of western North America, nearly a mile and a half high, is bordered by the lofty ranges of the Rocky Mountains; and Sierra Nevada systems ; the great Bolivian plateau is margined by the highest summits of the Andes ; and the loftiest plateau in the world, that of Tibet, is enclosed by some of the loftiest ranges of the earth.

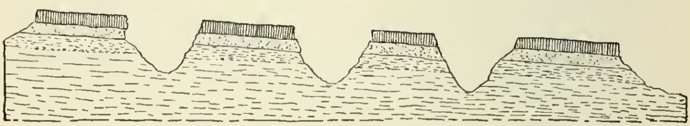
Mesas and table-lands are generally the result of erosion, or unequal weathering. The top of the mesa is commonly a layer of rock resting upon softer substance. The latter is protected from the action of the elements by the harder material and, in time a table-land is formed. Without the hard cap the surface would have been rounded off, leaving a hill instead of a mesa. As a rule, mesas and table-lands are the outlying or isolated remnants of plateaus. They are noticeable objects because of their flat tops and the steep cliffs or escarpments that form their slopes.



A SECTION ACROSS THE PLATEAUS AND FOLDS ADJOINING THE CAÑON OF THE COLORADO RIVER, WITH A BIRD'S-EYE VIEW OF THE TERRACES AND PLATEAUS NORTHEAST.—*After Powell.*

Distribution of Plateaus.—Most of the high plateaus are in the great highlands that radiate from north circumpolar regions; they face the Pacific and Indian Oceans. A series of lesser highlands borders the Atlantic Ocean, and these also contain plateaus. Although the plateaus have each a more or less definite outline they cannot always be considered apart from the highlands to which they belong. In places where the highlands border the sea, the plateaus may take the form of peninsulas; name several examples on the map of Asia.

Among the plateaus of the Asian Continent, that of Tibet is remarkable for its size and elevated surface, nearly three miles above sea-level; by what ranges is it partly enclosed? To the westward are the Pamirs, a series of grassy plateaus, like the "parks" of Colorado, about three and a half miles above the sea. In North America, the plateaus of the western highlands are a little more than a mile high, while those of the eastern highland have less than half that altitude. In South America the plateaus of the Andes are about two miles high, while those of the eastern region have less than one-third that height.



A DISSECTED PLATEAU, JOHN DAY VALLEY, OREGON

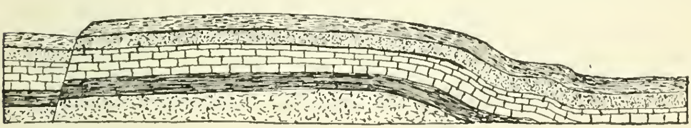
The sheet of lava at the surface has been removed here and there, leaving a series of mesas.

Economic Aspect of Plateaus.—Plateaus, especially those of a considerable altitude, are generally unproductive. In some instances they are so high that but little rain falls; in others the mountain-rims shut off the moisture that is borne with the winds. The rugged slopes and deep cañons almost always make commercial intercourse

very difficult, and sometimes impossible, except to the rudest methods of communication. Because of their unproductive character the high plateaus, as a rule, are sparsely peopled; and because of the lack of intercommunication the civilization of the native peoples is not usually of the highest type.

In the lower plateaus the conditions are different; there is generally a rainfall sufficient for the production of food-stuffs, and the land that cannot be cultivated is often well adapted to grazing; meat, cattle products and wool are almost always associated with these plateaus. The broken and dissected rock strata in many instances yield minerals and metallic ores useful in the arts and sciences, and the rugged character of the surface often furnishes an abundance of water-power. In the New England Plateau of the United States one may see the results of surface conditions in the production of water-power; in the Appalachian Plateaus, the results of coal and iron production; and in the Iberian Plateau and Australia the results of grazing facilities. The wool from these regions is the finest in the world.

Mountains.—Mountains are the most characteristic and remarkable features of the landscape. In form, they

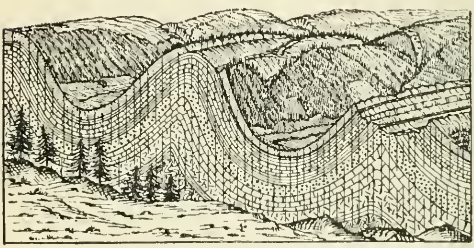


A SECTION ACROSS THE UINTA MOUNTAINS

A single fold with fault. After Powell.

are great ridges marked by a very rugged surface. In structure, they are folds or wrinkles in the strata of the rock envelope, or else they are immense blocks of rock, broken and partly upturned.

Mountains occur usually in *systems*, each of which consists of many ranges, together forming a distinct group. A very extensive system is sometimes called a *cordillera.* Thus, the Rocky and Andean Systems from the great Cordillera of the Western Continent Ranges or folds that seem to be continuations, one of the other, are said to be a *chain*, as the Sierra Nevada and Cascade Mountains. A single fold may be worn away so that the broken strata form *ridges* ; or the crest may be weathered so unevenly that it presents the appearance of a series of notches, thereby forming a *sierra.* Any part of the crest or summit materially higher than the rest forms a peak.[10] In most instances the peak is a high crag, or a pinnacle, but the name is also applied to volcanic cones, and to elevations that more properly are plateaus—as Broad Mountain, Pocono Mountain, and Broad Top, in the Appalachian system.



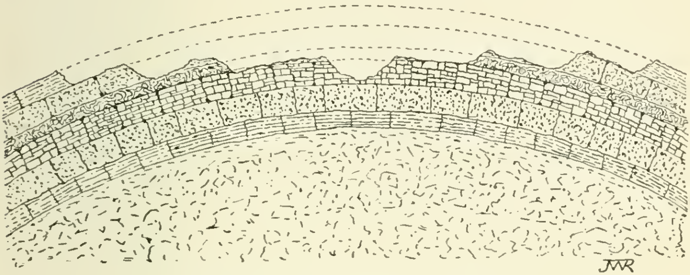
THE JURA MOUNTAINS

A series of gentle folds.

A mountain system is characterized generally by great extent, several of the more important exceeding four or five thousand miles in length. Name three of the greatest systems. A range, on the contrary, rarely exceeds a few hundred miles in length. It gradually takes form, continues a short distance, and then disappears, another to the right or the left taking its place. The rolling hills that in many instances form the approach to a system, are called *foot-hills* or, better, *Piedmont lands.* The hollow or depression between adjacent ranges forms an intermontane

valley; or if wide and apparently enclosed, a *park.* A valley that extends across the range is called a *pass,* a *gap,* or a *cañon.*

Nature of Mountain Ranges.—In the simplest form, as the Uinta Mountains, there is a single fold; in the Jura



SECTION OF A DISSECTED RANGE

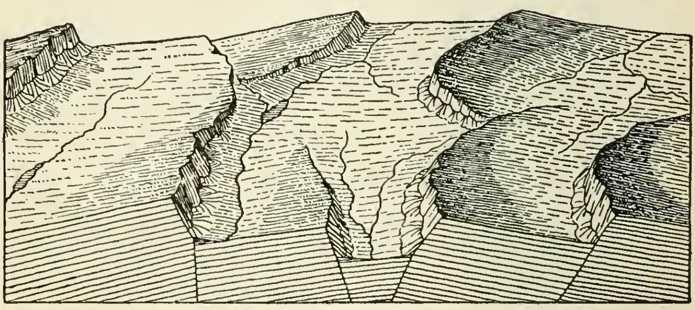
A single fold is dissected into a number of ridges.

Mountains there are several; in other instances, as the Alps, there has been a mashing and crumpling of the strata, producing results as irregular and complex as though the leaves of a book had been pressed and crumpled sideways by a great force.

The folding process takes place slowly—so slowly, in fact, that no means exist whereby it can be measured except after long intervals of time. This is shown by the conduct of certain rivers that flow across the folds. The streams cut their channels downward quite as fast as the folds are pushed upward. So when the fold has become a lofty range, it is severed transversely by the stream. Had not the upthrust of the fold proceeded more slowly than the downward cutting of the stream, the latter would be turned aside; in places this seems to have occurred, but even in such cases there is always evidence that the uplift of the range is very slow.

Excepting the core of granite, or similar rock that is present in the lower part of many folds, mountain-ranges are composed of strata of sedimentary rock. Moreover, it is a notable fact that the strata which form them are much thicker along the folds than elsewhere.[11] Thus in the Appalachian Mountains, the sediments composing the folds are about 40,000 feet thick, while the same strata in the Mississippi Valley are scarcely more than 4,000 feet in thickness.

Not all ranges present the aspects of folds, however. The ridges in the Great Basin of the United States are great blocks of sedimentary rocks that have been broken and tilted, and left with edges partly upturned. The Sierra Nevada and Cascade Ranges are both folded and broken, and their abrupt eastern slope is the edge of an immense block tilted toward the Pacific.



BLOCK MOUNTAINS, BASIN REGION

The upturned edges form the ranges.

The ideal system with its parallel folds exists, it is true, but it is not common. In most instances one finds a confused tangle of ridges and ranges, separated by intermontane valleys and crossed by gaps and passes. In not a few instances parallel ranges are connected by spurs, as in the

Sierra Nevada and Coast Ranges; and not infrequently several ranges seem to radiate from a massive uplift, as in the case of the Pamir highland, from which radiate the great folds that form the Himalaya, Tian Shan, Hindu Kush, and Suliman Mountains.

Physiographic Aspect of Mountains.—From the moment the process of uplift begins the waters of the atmosphere begin to level off the folds. In general, the more prominent a topographic feature, the more exposed will it be to the factors that produce erosion. And although nearly every part of the rock envelope is undergoing denudation, uplifted surfaces generally suffer most. As the process of elevation goes on, the mountain torrents carve the slopes of the range into a multitude of valleys, cañons, ridges, and hogbacks.

Not only are the flanks sculptured, but the crests are also worn away. The tops of the folds being considerably broken and, at the same time, the most exposed, little by little are removed, leaving the upturned edges in the form of long *ridges*. Most of the ranges of the Appalachian Mountains are ridges formed in this manner; there are few folds, but many ridges.

The amount of material removed from the slopes and crests of mountains is enormous. The crests of the Appalachian folds in Pennsylvania are scarcely more than two thousand feet high at the present time; but if all the material that has been removed could be again heaped upon them, their summits would be not far from ten miles high—about twice as high as the loftiest summits of the Himalayan folds. Usually the slopes and foot-hills are covered deep with coarse rock waste.[12]

Much—probably most—of this material has been removed by running water, but the moving ice sheet that at one time covered the northern part of the Appalachian

highlands was also a powerful agent in sculpturing their crests and slopes. Thus, in the North Atlantic States and New York, where they received the full force of glacial ice, the highlands, in places, are worn down almost to the sea-level. In Pennsylvania, where the wasting was less effective, they are about two thousand feet high. But in the South Atlantic States, beyond the limits of glacial ice, the various ridges are more than four thousand feet in altitude.

As a rule, therefore, mountain-ranges which show but few effects of weathering are comparatively young. The tilted blocks of strata that constitute the short ranges of eastern Oregon as yet are scarcely notched by streams, and are very slightly weathered. The ridges of Nevada are much more worn and carved, and the Rocky Mountains, though young as compared with the Appalachian folds, are very much worn. The Laurentian folds, the oldest in North America, are worn so greatly that their highest crests are only a few hundred feet above sea-level.

The character of the weathering and the landscape scenery as well depend partly on the rock and partly on the conditions of climate. In the Appalachian ranges all the forms are rounded, subdued, and graceful. In arid regions they are apt to be angular. The notched crests of western ranges of the United States and Mexico have suggested the name "sierra" (*saw*), the sharp, enduring crags of the Alps, "aiguille" (*needle*), "horn," and "dent" (*tooth*).

Distribution of Mountains.—Mountain-ranges seem to be incidental to highland regions. The great highlands that border the Pacific and Indian Oceans are rimmed throughout much of their extent by very lofty folds. In North America the Rocky and Sierra Nevada ranges are the rims of a high plateau whose surface is traversed by block ranges.

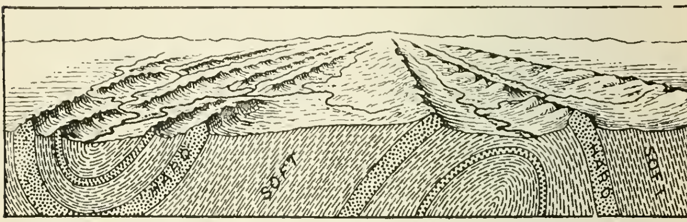
How is this statement borne out in the case of South America? of Australia? of Africa? It does not seem apparent, however, in the case of Eurasia. The great system of southern Europe, extending from the Caspian Sea to the Atlantic, belongs to the principal highland of Eurasia. The Alps form the northern, and the Atlas Ranges of Africa the southern rim. What sea fills the intermontane valley between them? A partly submerged chain extends along the east coast of Asia; name the peninsulas and principal island groups belonging to it. In general the great systems are nearest the Pacific and Indian Oceans.

Valleys.—The folding of strata into parallel ranges naturally forms valleys between them. The great intermontane valley of California, Oregon, and Washington is of this character. Name the ranges between which it is situated. Although interrupted by cross ranges it practically extends from Puget Sound to the Gulf of California. The valley, a part of which the St. Lawrence River now occupies, is similar in structure.

Most valleys, however, are the results of stream-cutting and the general weathering that comes from the action of water. Shenandoah Valley, the depression crossing Virginia, is an example. The rocks along the line of the valley were more easily worn away than those to the east and the west, and hence the valley resulted from their removal. The valley of the lower Hudson was possibly formed in a similar manner.[15]

In many instances the water wears away the broken rocks forming the crest of a range more easily than it can remove them elsewhere. In this way *canoe-shaped valleys* are formed at the summit of a fold. More commonly, however, the streams on opposite sides of a range wear their channels clear to the crest, partly breaking the lat-

ter down by making deep notches across it. Many of the passes in the Sierra Nevada and Rocky Mountains are examples;[16] and so, too, are the water-gaps of the Delaware, Susquehanna, and Hudson Rivers. Water-gaps are usually at the base level of the range; passes are usually high above it.



CANOE VALLEYS, APPALACHIAN MOUNTAINS

In a few instances the cross spurs that join parallel ranges enclose valleys of considerable extent. The Parks of Colorado, and the Pamirs, both frequently classed among plateaus, are examples. The latter are situated in a high mountain knot which, because of its great height, is often called the "Roof of the World."

Economic Aspect of Mountains.—Notwithstanding the fact that mountains are sparsely settled, and include a very large proportion of uncultivable land, they nevertheless exert a great influence on life, its history, and its industries. Ranges that face rain-bearing winds may be so lofty that they intercept all the moisture. How do the Cascade and Sierra Nevada ranges illustrate this? How does this affect the habitability of the region west of their summits? In various localities ranges at a considerable distance from the sea chill the winds passing over them and condense the moisture that otherwise would not be precipitated. Mountains, therefore, are factors in the distribution of rain.

The broken folds of the strata frequently expose metals and minerals that otherwise would not be accessible. Almost all the gold and silver, the mechanism of exchange, come from mountain-ranges; and so, also, does most of the copper, a metal necessary in the transmission of electric power. Practically all the anthracite coal and much of the best iron ores are associated with the rocks of mountain-ranges. The latter are, therefore, essential to the industries of mankind.

Mountains affect life and its industries mainly because they are barriers to intercommunication. The Greek peoples of early times found it much easier to spread along the shores of the Mediterranean and across the Ægean Sea than to cross the Balkan Mountains. For the first fifty years of our national history there was no transcontinental intercourse between the Atlantic and Pacific coasts of our country. It was easier to go sixteen thousand miles around Cape Horn than to traverse one thousand miles of mountainous surface.

The effects of intercommunication may be seen in the case of the Basques. More than two thousand years ago they were driven from the lowlands of Spain and France into the almost inaccessible valleys of the Pyrenees Mountains. During the succeeding years they have been so little in contact with the rest of the world that their language and customs have been changed but little in that time.

Because of the differences of climate on opposite sides of high ranges, the distribution of life-forms is greatly restricted. The dense forests of the Pacific Coast cannot extend across the Cascade and Sierra Nevada Ranges, because there is not enough moisture to support them. On the other hand, not many of the plants of the arid side of the mountains can cross the ranges and survive because the conditions of climate and soil are unsuitable.

A MOUNTAIN PASS, THE ANDES

Intermontane valleys are usually productive, and therefore densely peopled, areas. As a rule, their fertility cannot be easily impaired, because fresh soil is brought to them with every flood season. Because of the infertile region on either side, the industries of life are of necessity concentrated in the valleys.

Passes have even greater importance than valleys. A mountain-range is an obstacle to communication, and the pass is, therefore, the channel toward which intercourse must be concentrated. Railway routes through mountainous regions are always surveyed and built through the passes. Almost every railway to the various commercial centres of the Atlantic seaboard seeks a way through the passes and water-gaps of the Appalachian Mountains.

To Mohawk Gap, a pass that practically forms the principal route of traffic between the Great Lakes and the Hudson River, the wonderful development of New York City is due. It is more nearly level than any other route across the Appalachian Mountains, and for this reason it furnishes a standard by which freight rates between Atlantic seaports and the Mississippi basin are regulated.

Khyber Pass, a narrow defile a few miles east of Kabul, for more than two thousand years has been a part of one of the great overland routes between Europe and India. Indeed, it is the chief gateway to India; and the truth of the old saying, "whoso would be master of India must first make himself Lord of Kabul," is every day more and more emphasized. It is evident, therefore, that inasmuch as mountains are a barrier between peoples upon their opposite sides, all the intercourse and communication must be concentrated at the passes.

QUESTIONS AND EXERCISES.—Name and classify the vertical forms in the State in which you live. On an outline map, shade or otherwise designate the areas of highland and lowland, using such *contours,*

or lines of equal altitude, as may be available. If possible use the Relief Map of the United States noted below.

Make a relief model in sand or paper pulp of any locality, the topography of which you know—State, county, township, or other region of interest.

What results might occur were a mountain fold to be formed across the channel of a river?

Make a sketch restoring the plateau or mesa dissected by weathering processes, as shown on p. 64.

Name some of the benefits and the disadvantages resulting from the presence of the Appalachian Mountains between the industrial centres of the Atlantic Coast and the Mississippi Valley.

Explain why Fort Ticonderoga and Crown Point were important localities during the colonial wars. (*Consult any good map of Lake Champlain.*)

On an outline map of each continent, or grand division, draw heavy lines representing the positions of the principal mountain-ranges.

In what general direction does the rock waste of mountains move?—Explain why.

Give reasons why lowlands are more densely peopled than highlands.

COLLATERAL READING AND REFERENCE

McGEE.—The Piedmont Plateau. *National Geographic Magazine*, vii, 261.

WILLIS.—Physiography of the United States, pp. 169–202.

HAYES.—Physiography of the United States, pp. 305–336.

POWELL.—Exploration of Grand Cañon, pp. 181–193.

UNITED STATES GEOLOGICAL SURVEY MAPS, the following sheets: Tooele, Marion, Sierraville, Marysville, Kaibab, Farmerville, Spottsylvania, Mount Monadnock, Mount Mitchell, Hummelstown, and others.

NOTES

[1] The difference in the surface features of these plains is due partly to altitude and partly to rainfall. The Pampas resemble the high plains east of the Rocky Mountains. Both slope from a high to a low level, and both are covered with "bunch-grass"—that of the Pampas being a very coarse species that grows to a

height of four or five feet. The Llanos are watered by periodical rains and are alternately a swamp and a sun-baked desert. The Silvas lie in a region of almost constant equatorial rains; hence they are adapted to tropical forestry. The Pampas and Llanos produce wild cattle and horses; the Silvas, rubber and ornamental woods.

[2] It will be swept by simoon winds because it will be practically a desert, for it is in such regions only that simoon winds are found. The same is true of the valley of Great Salt Lake: it will be a desert region as soon as the lake disappears.

[3] Alluvial plains are the most productive lands in the world. Because their soil is constantly replenished by overflows and freshets they rarely wear out; the nutrient elements are supplied about as fast as they are exhausted.

[4] The Atlantic Coast Plain varies from a few miles to more than one hundred in width. The more recently formed parts are covered with pines; and a broken, narrow belt of pine forest extends from Chesapeake Bay almost to the Rio Grande. To the eastward of the pine barrens is a belt of sand flats and swamps of still more recent origin.

[5] Diluvial plains in places are strewn with large bowlders and covered with a "drift" composed of sand, unsorted gravel, clay, and bowlders.

[6] A similar plain involves the northern part of North America. In the New World, however, it loses many of the topographic features of a plain and is, perhaps more accurately, a low, but rugged plateau. Its slope, however, like that of the Eurasian plain, is toward the Arctic Ocean, and like the latter plain, its coastal portion is bordered by tundras. Generally considered, this plain is a vast basin almost shutting the Arctic Ocean from the rest of the sea.

[7] Plains are quite as subject to the same weathering processes as are mountains and plateaus, but because of their gentler slopes, the *rate* of erosion is not so great as in mountainous regions. The bluff lands along the Mississippi and some of its tributaries are thus dissected. Their complete degradation is a matter of time only. The higher parts of the Atlantic Coast Plain have been also greatly dissected by streams. In many instances the stream valleys and flood plains cover an area equal to the inter-stream uplands. In strong contrast are the low,

recently formed marine plains along the southern coast of New Jersey, and the still younger tule plains of the Sacramento Valley. In these the rivers have hardly been able to select their channels, much less to extend them.

[8] A high plateau sparsely covered with vegetation is much more readily dissected by streams than a grass-covered surface. The region through which the middle course of the Colorado River flows is an example. Here the plateau has been cut to a depth ranging from three thousand to six thousand feet. The region is one of deficient rainfall, however. Extensive corrasion is shown along the beds of the streams that rise at a distance in snow-clad mountains. Only a small part of the plateau as yet has been removed, and large areas show but little signs of dissection. In other parts, however, such as the "Land of Standing Rocks," denudation has been enormous, and only the towers of harder rocks remain. A complex dissection may be seen in various parts of the Appalachian highlands. Here, because of a greater rainfall, the streams have formed a network of cañons throughout the regions.

[9] Such formations are very common in the lava-covered regions of the Sierra Nevada and Cascade Mountains; they are also found in the Piedmont lands of western Texas.

[10] There are many examples of isolated peaks, or "monadnocks," in those mountain-ranges that have been very greatly worn. Mount Holyoke is one of several examples in Massachusetts. It was not thrown up in its present form; on the contrary, it was left when the rest of the range, being softer, was worn away. Mount Monadnock, New Hampshire, is a similar example. Isolated ridges or ranges are more common, and excellent examples may be found in the Great Basin.

[11] Not only were the deposits that became sedimentary rock thicker before the folding took place, but they were made still thicker by side pressure and crumpling.

[12] At the mouth of every cañon there will be found a fan-shaped pile of coarser material called *talus*. A pile of talus is usually found at the bottom of every steep, rocky cliff.

[13] A large part of Rhode Island and Connecticut constitutes the base of an old mountain highland that has been worn down almost to sea-level.

[14] Both valleys have been modified by water, the depression

having been submerged, partly filled with sediment, and re-elevated.

[15] It is not unlikely that the process has been more complex, and that periods of elevation have alternated with those of rest. Old shorelines and deposits of river gravel occur all along the lower river. The numerous clay banks seem also to have been deposited by slack water. The lower part of this valley is now practically an estuary.

[16] Among the famous passes are Argentine, 13,100 feet, the highest wagon road pass in the world ; Marshall Pass, 10,900 feet, one of the highest railway passes in the world ; Alpine Pass, 13,550 feet, and Mosquito Pass, 13,700 feet—all in Colorado. Simplon, St. Bernard, and Brenner are famous passes across the Alps, and for centuries they have been highways of commerce. A railway pass across the Andes is nearly 14,000 feet above sea-level.

In many instances the pass is not fully surmounted ; instead of building the railway over the divide, it is more economical to construct a tunnel under it. Some of these tunnels are marvels of engineering skill. St. Gotthard and Mont Cenis tunnels through the Alps ; Hoosac tunnel through the range of the same name in Massachusetts ; San Fernando tunnel, in California ; and the tunnel of the Transandine Railway are examples : each is one mile or more in length. In other cases the railway surmounts the range by a series of long and intricate loops, crossing and recrossing itself through tunnels that often are sharply curved. Near Caliente, California, the Southern Pacific Railway is built in sinuous loops aggregating about twenty miles in order to cross a divide scarcely two miles from the head of the valley. The famous loops of the Colorado Midland over Hagermans Pass is also a well-known example of the railway builders' skill.

CHAPTER V

DESTRUCTIVE MOVEMENTS OF THE ROCK ENVELOPE: VOLCANOES AND THEIR PHENOMENA

Of the various phenomena that attend changes in the level of the rock envelope, two of them, volcanoes and earthquakes, are noteworthy because the results are more

VESUVIUS, A TYPICAL CINDER CONE

From a model.—After Nasmyth.

or less destructive. In the one case, great quantities of molten matter are ejected from fissures or vents, covering very large areas; in the other, there is a movement at

some part or other of the rock envelope, so sudden that a tremor, or even a severe shock, occurs.

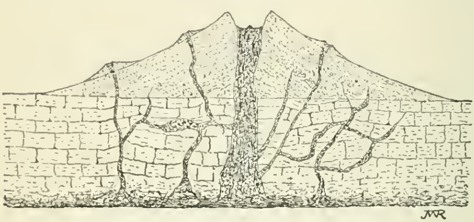
Volcanoes.—A channel or vent in the rock envelope from which great quantities of steam and molten rock are ejected constitutes a *volcano.*[1] In most instances a great deal of material, in the form of clots of half-molten rock, fall about the vent and build up a conical pile, sometimes called a "volcano," but more properly, a *cinder cone.* At the top of the latter is a cup-shaped depression called the *crater* or, if very large, the *caldera.*[2]

Volcanoes showing any display of energy are said to be active, quiescent, or inactive, according to the character of their energy; those in which all signs of activity seem to have disappeared are said to be extinct.[3] In a few instances the activity seems to be continuous. Thus the caldera of Mauna Loa nearly always contains lava in its molten condition, and Stromboli, "the Lighthouse of the Mediterranean," has been a mariner's beacon for more than two thousand years. Most active volcanoes, however, are intermittent in action, alternating their eruptions with long periods of rest.

Phenomena of Eruption.—In certain respects all volcanic outbursts are similar; that is, lava and steam are ejected from a subterranean source, and the matter ejected is forced out of a vent or channel in the rock envelope. Beyond this, however, the various types of eruption have but little in common. In most cases the eruptions are very destructive. Frequently they are preceded by earthquakes, though these warnings are by no means always present. Generally they begin with explosions that rend the top of the cinder cone in fragments. In some instances the plug of hardened lava that filled the channel is blown out, but quite likely a new channel is formed at the one side or the other.[4]

A vent once made, the water that had accumulated about the cinder cone, together with mud and fragments of rock, are hurled upward; an outrush of steam mingled with mud and rock waste follows, and a cloud of inky blackness quickly envelopes the cone. The condensing steam, with which sulphureous vapors are sometimes mingled, produces heavy rains; and if sulphur gases are present, the rain may become so corrosive that vegetation is blighted and in many instances the crops are destroyed.[5]

A flow of lava follows. At first the lava is ejected with almost explosive violence, but after awhile the flow becomes steady and regular.[6] The ejection of material takes place, not only at the main vent, but at the score of new ones formed on the flanks of the old. At each vent small *monticules*, or *parasitic cones*, are quickly formed, and the eruption from them does not differ materially from that at the main vent.



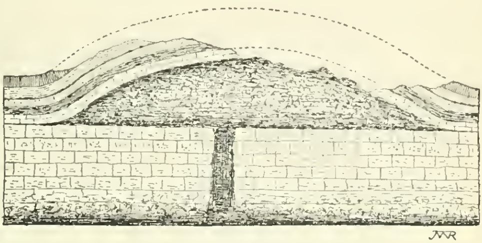
IDEAL SECTION OF A VOLCANO

Minor eruptions are taking place through fissures in the flanks of the cinder cone, building parasitic cones.

Volcanoes such as Stromboli display but comparatively little explosive energy. From an overhanging crag of this volcano the eruption may be safely studied. At intervals of fifteen or twenty minutes a gigantic bubble begins to form in the caldron of seething lava. In a few moments it rises to the top and bursting, hurls a shower of lava clots into the air.[7] The eruptions of the Hawaiian volcanoes are materially different from those of the Strombolian or the Vesuvian type. Instead of the intermittent bubbles of Stromboli, or the violent outburst of Vesuvius,

the lava rises in the caldera until it overflows the lowest part of the rim.[8] The flow of lava—often an enormous quantity—continues for several days, or perhaps for several weeks, and then subsides as quietly as it began.

The fissure eruptions that occurred in previous geological periods seem to have somewhat resembled those of the Hawaiian volcanoes. In these eruptions there were apparently none of the phenomena that mark outbursts of the Vesuvian type. Great fissures were formed, and through these the lava was forced.[9] In some instances there was an enormous flow of lava; in others the lava merely filled the fissure and hardened, leaving dykes of volcanic rock. The plains of the Columbia are the remnants of a flood of lava from fissures in the Sierra Nevada mountains. The Palisades of the Hudson form a dyke of similar character.



A LACCOLITE

A section through one of the Henry Mountains. The dotted lines indicate the strata removed by erosion.

In a few instances a flow of lava, thrust upward, has raised the outer strata of the rock envelope in much the same manner that a blister of the skin is formed. No extrusion of lava took place, and, as a rule, none reached the surface. Irruptions of this kind form what are commonly known as *laccolites*. The Henry Mountains, a detached group of knolls in Utah, are examples.

Products of Eruption.—Excepting the very small amount of sulphur gases emitted, practically but two substances are ejected from volcanoes—steam and lava. In

the eruption of Vesuvius that occurred in 1872, it is estimated that ninety-eight per cent. of the material ejected consisted of steam. From the Hawaiian volcanoes, however, the matter thrown out consists almost wholly of great quantities of lava.

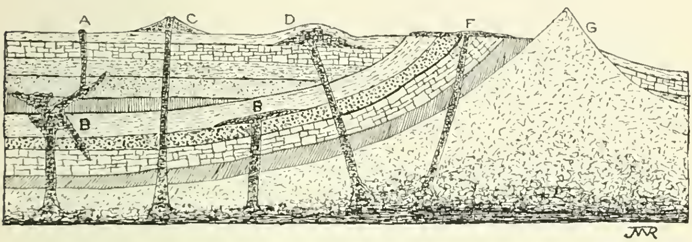
The term *lava* includes every form of molten rock of volcanic origin. Lavas, therefore, differ not only in appearance, but in chemical composition as well. In many instances the lava resembles furnace slag, and has about the same composition. Sometimes it is vesicular, or spongy; pumice-stone, or "volcanic froth," is so porous that it floats on water. Obsidian, or "volcanic glass," another form, does not differ materially from black bottle-glass. The sponge-like clots of lava that accumulate about volcanoes form *scoria;* they are suggestive of furnace "clinkers."

A misunderstanding of volcanic phenomena has led to the adoption of certain names that often give erroneous ideas of volcanic action. There are no "flames" about volcanic outbursts; the so-called flames are merely the reflection of the white-hot lava from the under surface of the dense clouds of steam.[10] "Smoke" is also absent, except as the clouds of dust and steam can be thus called. Volcanic "ashes" are not ashes at all; they consist merely of finely divided lava. It is thought that this form of lava results from the action of steam which, forced through the lava by intense pressure, carries much of it along in a fine, powdery state.

Most lavas are readily decomposed by the action of air and moisture, and the Hawaiian lavas make excellent soil in the course of a very few years. The economic value of lavas, therefore, may be considerable. Sulphur, or "brimstone," is a common mineral in and about the craters of volcanoes. It is formed by the action of certain sulphur

gases that, on mixing, decompose each other and deposit the sulphur in the shape of crystals.

Nature of Volcanoes.—That the cause of volcanic action is due indirectly to the gradual shrinkage of the crust of the earth is admitted by most geographers. To what extent the process of contraction becomes a direct cause, however, is a matter of uncertainty, and one upon which there is a great diversity of opinion. It is generally conceded, also, that the material ejected comes, not from an assumed "liquid interior" of the earth, but is formed at a very moderate depth below the seat of eruption.



FORMS OF ERUPTION

A, a dyke; B, E, subterranean intrusions; C, a cinder cone; D, a laccolite; F, a lava sheet; G, granite core of a range.

Various theories have been advanced to account for the possible causes of eruption, but of these only one or two are supported by positive evidence. The pressure that results when the rock layers fit themselves about a shrinking interior is sufficient to heat the parts upon which the pressure is exerted, far beyond the temperature of fusion; and if a break or fracture takes place, the pressure being relieved at that point, the superheated rock at once liquefies and is forced out of the fissure. The intrusion of water upon molten matter undoubtedly causes the explosive features of the eruption, but it is improbable that this is the prime cause.

In a few instances there seems to be more or less relation between volcanic vents situated at no great distance from one another. Thus, while Vesuvius was so long inactive, Epomeo on the island of Ischia was active; but after the eruptions of Vesuvius began again, Epomeo became dormant. A similar condition possibly obtained in past times, for the Phlegrean Fields, an area south of Vesuvius, is honeycombed with old craters through which eruptions took place at successive intervals.

The same phenomenon is observed in the case of the Hawaiian and the Ecuadorean groups. Activity is usually confined to a single caldera, and if this becomes dormant for any length of time the seat of activity is transferred to another vent. In the cases of the Italian and the Ecuadorean groups, the cessation of all activity is usually followed by a period of frequent and destructive earthquakes.

Results of Vulcanism.—Notwithstanding their stupendous display of energy, the physiographic effects of volcanic outbursts are comparatively unimportant, and as a rule they are confined to the vicinity of the volcano. The most noticeable feature is the cone or dome that popularly is called a volcano or volcanic peak. Each volcano builds its own cone, and in many instances the cones have been built along the folds of mountain-ranges. In several cases they have been formed successively along the line of the fold at no great distance apart.

The lava usually collects at the vents, extending laterally outward, and at the same time building the cone higher and higher. The successive eruptions of the calderas of Hawaii have formed a mass 14,000 feet high that covers an area as large as the State of Connecticut. Most of the volcanic mountains of the Hawaiian Islands are dome-shaped rather than conical, the shape resulting from the

very liquid condition of the lava and the absence of ashes and scoria.

Some of the lava flows of the Iceland volcanoes have been extensive. Of the thirteen or more cinder cones in the island Hekla and Skaptar Jökul are the best known because of the frequency of their eruptions. In 1783, there occurred a flow of lava from the latter that continued for two years. Two streams flowed in nearly opposite directions from the crater, one forty, the other fifty miles in length. More than 1,000 square miles in area were covered by the lava. A score of villages was swept out of existence. Streams were dammed by the lava and

A LAVA FLOOD, HAWAIIAN ISLANDS

their floods added to the destruction. Thousands of cattle were killed, and a large part of the population perished in the famine that resulted from the eruption.

The ashes sometimes accomplish more ruin than that which results from the lava flow and the corrosive rain.

Herculaneum and Pompeii were destroyed by the eruption of Vesuvius A.D. 79. Pompeii was covered with loose material, and much of the city has been excavated in recent years. Herculaneum received a heavy fall of rain in addition to the ashes, and the latter were cemented into a tolerably hard rock.

In many instances the ashes have been hurled to a great distance, being in part carried by the wind. During the eruption of Tomboro, in Sunda Strait, dwellings forty miles distant were crushed and large areas of forestry were destroyed. Similar, but more appalling effects resulted from the eruption of Krakatoa, also in Sunda Strait. The explosions lasted for two days and culminated with the disappearance of half of the island. Forestry seventy-five miles away was crushed by the falling mud and rain, and the fine material covered the city of Batavia to a depth of several inches. Some of the lighter dust was carried by the wind to a distance of more than 1,000 miles.

Islands are both formed and destroyed by the outbursts of marine volcanoes. Off the coast of Tunis, near the site of Carthage, a reef called Graham's Island was formed during an eruption, and remained in existence for several years. It then gradually settled below sea-level and disappeared. Several new islands appeared in the group of the Azores, during eruptions, but they gradually disappeared. A more remarkable case is that of Santorini,[11] an island in the Greek Archipelago, which was formed as a result of eruptions. It is now inhabited.

Fissure eruptions are noted mainly for the enormous flows of lava. From one or more of these fissures in the Sierra Nevada ranges there occurred a flood of lava that covered more than one hundred thousand square miles. Large areas of California, Oregon, Washington and Idaho were engulfed, and in several places the Columbia River

was pushed out of its channel. In many places small cinder cones have been formed on the surface of the lava, each being an eruption upon an eruption. In places, the sea of lava is nearly four thousand feet deep, and the average depth is not far from one thousand feet.

Vulcanism seems to be a trustworthy index of processes going on within the earth's crust which affect the level of a region. Careful measurements have shown that, in regions of volcanic activity, an elevation of the surface is taking place. Thus, along much of the Mexican and South American coast, where volcanic forces are active, upheaval is taking place. In the South Pacific Ocean, on the contrary, where vulcanism seems to have recently ceased, there has been a considerable subsidence. It cannot be said with certainty, however, that these are matters of cause and effect.

Distribution of Volcanoes.—Volcanoes are commonly found along the lines of the younger mountain folds, and they are almost always near the sea. The Pacific Ocean is nearly girdled by chains of mountains that are comparatively young, and in these folds are situated a majority of the active and dormant volcanoes of the earth.

Another short chain extends along Java and the remaining Sunda Islands to New Zealand. It contains about one hundred active and dormant volcanoes, and is the chief seat of volcanic activity on the earth. The Hawaiian group is about the only one situated in mid-ocean. In what direction does it extend? This chain is about a thousand miles long. The seat of activity, however, is confined mainly to the island of Hawaii, on which there are three calderas—Kea, Loa, and Kilauea.

A chain of volcanic islands extends from Jan Mayen island through Iceland, the Azores, Canary, and Cape Verd Islands, southward as far as Tristan da Cunha. An-

other extends through the West Indies, but it contains no volcanoes at present active. Graham Land, in the Antarctic Continent, contains at least two volcanoes that have been active in recent times.

Among American volcanoes the Peruvian and Ecuadorean groups are famous for their great height. Name three of them. The Mexican group contains four of interest, because they are so far inland. Find them; in what direction does the line extend? They are active or quiescent at short intervals.

The North American group contains a great many dormant and extinct cones; but at least four—Shasta, Tacoma (or Rainier), and Lassen must have been active at no greatly remote time. A small cone near Lassen Peak has been in eruption within fifty or sixty years, and the stumps of trees, many of them in a good state of preservation, are still protruding through the sheet of lava.

Cinder cones and volcanic "necks" are abundant all through the plateaus of the Western Highlands. In Arizona there are several hundred. One of the most imposing, San Francisco Peak, has been in eruption within recent times. In New Mexico there are also many small cones. Almost all the high peaks of the Cascade and Sierra Nevada ranges are cinder cones.

The Aleutian group contains about thirty cones, quiescent and active. One of these, Bogoslov, north of Unalaska, has been in eruption almost constantly since 1880. Many of the peaks of the West Indies are cinder cones, but none has been active in recent times. The remains of old cones are abundant in the Appalachian and Laurentian Mountains, but they seem to have been extinct since early geological times. One of them, Mount Royal, has given to the city of Montreal its name.

QUESTIONS AND EXERCISES.—Explain the nature of the so-called smoke, flames, and ashes of volcanic eruptions. Why are these terms inapplicable ?

Prepare a written description of the geographic distribution of volcanoes, taking into consideration their position with reference to mountain-ranges, proximity to the sea, latitude, and situation with reference to continents and islands. Consult the map, p. 92.

Note the features in the diagram, p. 88, and prepare a brief description of the various ways in which lava is extruded.

COLLATERAL READING AND REFERENCE

PLINY.—Letters—Book vi., 16–vi. 20.

SHALER.—Aspects of the Earth, pp. 46–97.

" First Book of Geology, pp. 88–97.

LE CONTE.—Elements of Geology, pp. 89–103.

REDWAY AND HINMAN.—Natural Advanced Geography, p. 12.

UNITED STATES GEOLOGICAL SURVEY.—Shasta and Lassen sheets.

NOTES

1 The channel or tube is the essential part of the volcano, and the "mountain" or cinder cone is merely an incidental feature. The latter is rarely absent.

2 The craters of the earth are exceedingly small, compared with those of the moon. Terrestrial craters are rarely more than half a mile in diameter ; lunar craters, on the contrary, frequently exceed twenty or thirty miles in diameter ; Tycho and Copernicus, are each more than forty miles.

3 As a rule, such volcanoes are rarely distinguishable, except by most careful investigation. Usually the cone has been almost obliterated, nothing remaining except such masses of lava as are not easily altered by the action of moisture and atmospheric elements. Mount Tom, Massachusetts, is an excellent example of an old volcano.

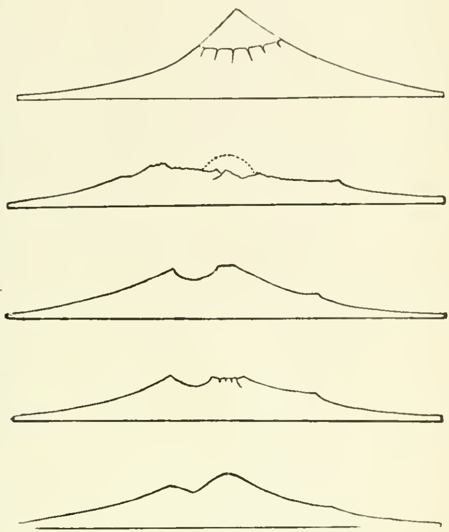
4 The eruption of Vesuvius in 1756 took place, not at the former crater, but a little to one side. One of the old crater walls remained standing, and for many years was called Monte Summa. During the eruption of 1872 a large number of vents was formed,

DISTRIBUTION OF VOLCANOES

and the flanks of the mountain were dotted with monticules. Professor Palmieri, who remained in his observatory on the mountain during the entire period, said that the whole side of the cone "seemed to sweat fire at every pore."

[5] The sulphur compounds combine with the steam, making sulphurous acids, and not infrequently the acid dissolved in the rain is strong enough to destroy vegetation.

[6] It behaves exactly as though it were forced out by gases under extremely high pressure, the elasticity of the medium that constitutes the power being the most noticeable feature.



ALTERATIONS IN THE SHAPE OF VESUVIUS

A.D. 63, 79 to 1631, 1767, 1822, 1868.

[7] The phenomena are simply those exhibited by a viscous body in a state of slow boiling, and are perfectly illustrated in the slow cooking of oatmeal. It is a significant fact that when the barometer is low, the level of the lava is higher than at other times.

[8] There is evidence of the presence of gases in the Hawaiian lavas, not under pressure and endeavoring to escape, but in a condition of absorption or occlusion. Occasionally, clots of lava are shot into the air, and as soon as the ejected mass perceptibly cools, its absorptive power is lessened, the escaping steam or other vapor blowing the viscous lava into the fine, tenuous threads known as "Pele's hair." The threads thus formed are so gossamer-like that they are carried a long distance by the wind.

[9] There is a tendency to consider the vulcanism of past epochs as *crater* eruptions only. That such eruptions have occurred in

prior epochs cannot be denied ; old craters and the lava plugs that filled them are found in great numbers in many parts of the earth. Most, if not all, of the great lava floods, however, came, not from craters, but from *fissures*. No crater in the world is large enough to have ejected a lava flood in the manner in which that of the Oregon and Washington flood was spread. Calderas like those of Hawaii would have built up a dome-shaped mass of *ejecta*. The lava flood in question was a *sheet*. It could have come from nothing but a fissure, and the fissure must have been many miles in length. Cinder cones and craters are found here and there on the surface of this vast sheet. In each case the cone and its crater represent a volcano that formed on the lava flood after the surface had hardened. This fact indicates that vulcanism occurs just as readily with a *supramontane* as a *sub-mountain* reservoir. In many instances there has been nothing more than a mere filling of the fissure—an *intrusion* of lava, but no *extrusion*. Not infrequently the upper edges of the fissure walls have been worn away, leaving the harder volcanic rock in the form of a ridge or dyke. The Palisades of the Hudson are an example. The Devil's Slide, in Weber Cañon, Utah, is also an illustration. In this instance there are two dykes about twenty feet apart, the groove between them being of softer rock.

[10] This may be illustrated by a very familiar example. When a train of railway coaches passes through a long tunnel, a flood of mellow light now and then illuminates the tunnel and the interior of the coaches. The light comes from the fire-box of the locomotive. When the furnace door is opened the light of the glowing coal is reflected from the steam that fills the tunnel. Each globule of water dust is a tiny mirror, and as a result the tunnel is flooded with light. In the case of the volcanic "fires" the light is reflected from the under side of the cloud of steam.

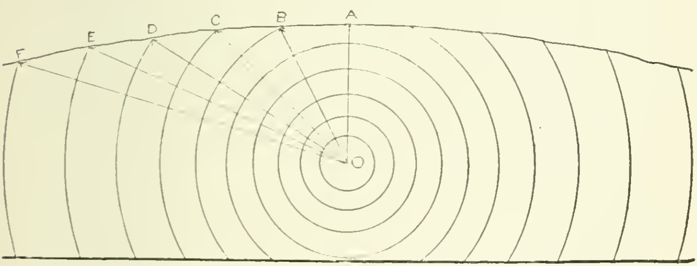
[11] This island, better known as Thera, is a few miles north of Crete. According to one myth it grew from a clod of earth hurled from the ship Argo ; according to another it was the product of submarine fires. Both legends are a testimony to its volcanic origin. The topography of the island was considerably altered by an eruption that occurred in 1866. The area covered by ashes and scoria quickly became cultivable, and has since added no little wealth to the island.

CHAPTER VI

DESTRUCTIVE MOVEMENTS OF THE ROCK ENVELOPE: EARTHQUAKES

Rigid and solid as they seem, the substances that form the rock envelope are more or less elastic. This is noticeable when an underground explosion [1] occurs, or even when a very heavy weight falls to the ground; the latter trembles for an instant, causing a slight shock.

Any instantaneous disturbance, therefore, such as a subterranean explosion, the collapse of a cavernous space, or



THE PROGRESSION OF EARTHQUAKE WAVES

the sudden breaking of strata, causes a vibration or trembling of the surrounding rock. These tremors or earthquakes may be perceptible for several seconds, or even for so long as a minute. The shock, moreover, may involve an area of several thousand square miles.

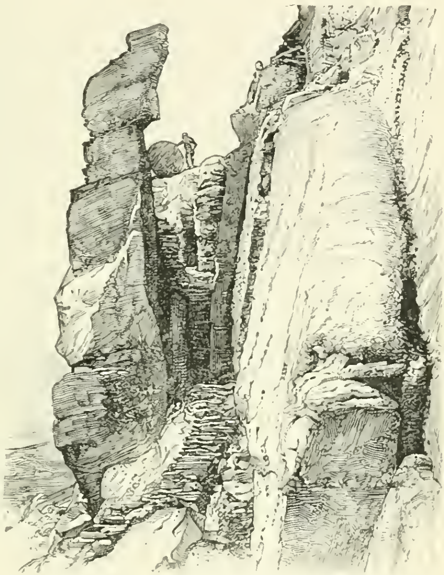
Nature of Earthquakes.—No matter how far below

the surface of the rock envelope the centre of the disturbance may be, as soon as the vibrations reach the surface they behave just as do the circular waves that form when a stone is thrown into still water.[2] In the diagram on page 95 the shock originates at O; at what place will the resulting wave have an up-and-down motion? These are called *vertical* waves. As the successive waves move outward, little by little the vertical movement gives place to one that is both horizontal and progressive, and the latter may be called a *horizontally progressive* wave. At what part of the diagram are the waves most nearly horizontal? Where do they partake both of the vertical and the progressive character?[3]

The effects that have been observed, however, indicate that the tremors or vibrations do not always spread out so evenly from the centre of disturbance as is the case with the waves resulting when a stone is thrown into water. Some kinds of rock seem more elastic than others, and so the concentric waves, instead of remaining circular in form, become irregular in shape. If the waves of water strike an unyielding surface, they are reflected, the reflected wave often crossing the original at oblique angles. Rock waves, it is thought, are similarly reflected, and sometimes they produce effects that would seem as though there had been a vorticose, or whirling movement.[3]

Although the surface waves of earthquakes bear a close resemblance to the circular waves formed by dropping a stone in water, it must be remembered that they differ greatly in velocity and energy. The latter progress only a few yards a minute; the former have the velocity more than double that of the swiftest projectile fired from a modern gun, travelling at a rate that varies from thirty to forty or more miles a minute.[4] The velocity of the wave depends partly on the elasticity of the material

through which it travels, and partly on the energy with which it is propagated. In hard, crystalline rock it travels rapidly and extends a great distance; in sand and loosely coherent rock the velocity is much slower, and the waves quickly lose their energy.[5]



A ROCK COLUMN LIKELY TO BE OVERTURNED BY AN EARTHQUAKE

The rock has broken away from the cliff, splitting along a naturally formed plane. Rock waste, falling into the crevice, has become saturated with water, which by freezing, has expanded and pushed the mass farther and farther from the cliff.

In the case of severe earthquakes a series of shocks follow one upon another with increasing intervals of time.[6] The first shocks are commonly the most violent. The duration of the shock is not perceptible to the senses for more than four or five seconds, but careful measurements by the seismograph, an instrument for the detection of shocks, show that it may last for more than a minute. In many instances a shock seems to consist of a single violent thump.[7]

The focus of the shock may vary from a short distance to several miles below the surface of the earth. The average distance is not far from six miles. The area involved in the earth-waves may be either circular or

elliptical.[8] The diameter of the area seldom exceeds one thousand miles.[9]

Attending Phenomena.—Earthquakes are frequently attended by sounds. Sometimes the latter resemble low, rumbling thunder; more commonly, however, the noise is like that produced when a heavily loaded wagon goes rapidly down a gravelled incline.

In the great majority of earthquakes the effects are not severe; they rarely extend beyond the stopping of clock pendulums, and the swinging of chandeliers, or the breaking of delicate substances. In severe shocks the walls of houses are wrenched and cracked, and the ground is fissured. In disastrous shocks buildings are shattered and the surface of the earth is seamed with deep fissures and chasms. In several instances lakes[10] have been formed or, perhaps drained, and stream channels changed.

If the centre of the shock is in or near the ocean it is commonly followed by a series of gigantic waves, incorrectly called "tidal" waves. Following the Lisbon earthquake in 1755, enormous waves rolled in from the sea, and wrecked whatever the earthquake had left.[11] The ocean-waves that followed the earthquake at Arica, Peru,[12] carried the United States Steamship *Wateree* nearly seven miles inland, leaving her stranded in a dry stream bed.

Cause of Earthquakes.—It is generally believed that earthquakes are the result of similar, but very rapid movements of the rock envelope that fold the strata into mountain-ranges and force molten lava from volcanic fissures. If the strata are slowly bent, no vibratory effect is noticeable, but if the strain increases until a fracture or a collapse takes place, the shock produces the vibrations that constitute the earthquake.

When fissures are formed, usually one wall slips upon the other, so that the two edges are no longer in the same

level.[13] The resulting inequality is called a *fault*, and wherever such faultings are found, they indicate, if not an earthquake, at least a surface disturbance. The existence of such faults, therefore, is evidence that the outer shell of the earth is constantly under stress[14] at some point or another, and that the release of the strain produces the earthquake.

AN EFFECT OF THE EARTHQUAKE AT CHARLESTON

The crack when first formed was about two feet wide. From a photograph.

Distribution and Occurrence of Earthquakes.—No part of the earth is free from earthquakes, and recent observations have shown that, in some part or other, they are of almost daily occurrence. As a rule, however, they are so feeble that scarcely one in fifty is noticeable, or even perceptible, without the aid of instrumental measurements.[15]

As in the distribution of volcanoes, earthquakes are of more frequent occurrence in younger mountain-ranges

than in the older ones. They are still less frequent in plains, unless the latter are undergoing a process of uplift or depression. They also accompany most volcanic disturbances.[16]

The study of several thousand earthquakes shows that shocks are a little more frequent when the earth is nearest the sun, and that they are also more prevalent when the moon is nearest the earth.[17] An explanation for this is not hard to find. Owing to the tendency to adjust itself, some part or other of the rock envelope is constantly under an increasing stress. But when the earth approaches either the sun or the moon, the increased mutual attraction adds its force to the strain; the latter is overcome, and a shock results.

QUESTIONS AND EXERCISES.—If you live in the vicinity of a body of water, study the waves that form when a good-sized stone is tossed so that it falls vertically into still water.

What is the relative position of the vertical and the horizontally progressive waves? Repeat the experiment until the results obtained are familiar.

If possible, clamp a brass or metal plate, about a foot square, to a firm table, so that the clamp holds the plate at its centre. Sprinkle dry sand on the plate and draw a violin bow across the edge. From the figures produced by the sand note the direction and character of the vibrations.

COLLATERAL READING AND REFERENCE

ROCKWOOD.—Notes on American Earthquakes.
SHALER.—Aspects of the Earth, pp. 1–45.
LE CONTE.—Elements of Geology, pp. 154–171.

NOTES

[1] Thus, the explosion under Flood Rock, for the purpose of clearing and widening Hell Gate Channel, produced an earth shock that differed in no material principle from those produced

by natural causes. The earth shock resulting from this explosion was recorded at a distance of nearly forty miles from Hell Gate. The velocity of the wave varied from 5,000 to 8,000 feet per second in the vicinity of the explosion.

[2] The vibrations as they form underground are spherical waves and much like those formed in the air by the discharge of a fire-arm or the ringing of a bell. When the waves reach the surface of the rock envelope they spread out in the form of circular waves.

[3] Such waves have a terrific shattering force; but those in which the horizontal and vertical components are combined are even more destructive: they not only shatter, but they produce a rocking motion as well. Vertical vibrations may only shatter a building; a "roller" will not only shatter, but overthrow it.

[4] It has been calculated that the amplitude, or up-and-down motion, rarely exceeds one-quarter of an inch in height; and ordinarily, in severe shocks, it is seldom more than one-twentieth of an inch. The horizontal oscillation is scarcely more than half an inch, and even when it is not more than half as much, the shock has considerable shattering power.

[5] During the earthquake at Riobamba, Ecuador, a vertical movement of more than two feet is said to have been observed. The statement, however, is not considered authentic. At all events, the energy was sufficient to hurl heavy objects a hundred feet into the air. The bodies of men were thrown several hundred feet across the river.

[6] At St. Thomas, one of the Lesser Antilles, the shocks of 1868 aggregated nearly three hundred in number. The earthquakes that shattered San Salvador, the capital of the State of Salvador, lasted for about ten days. The Charleston earthquakes did not cease for nearly a month, and a hundred similar instances might also be added. All this accords with the well-known law that a mass of rock envelope, in changing its foundations, cannot adapt itself to its new position at once, but does so little by little.

[7] Many of the California earthquakes are of this character.

[8] The elliptical form is especially noticeable in mountainous areas, and in nearly every instance the major, or long diameter of the ellipse, coincides with the trend of the range or system. The reason therefor is the fact that the strata of rock are more elastic along than across their masses.

[9] In several instances, however, the area involved has far exceeded this. Thus the shock that in 1755 destroyed Lisbon was felt at a distance of about twenty-five hundred miles. The sea-wave is propagated to a much greater distance.

[10] The earthquake that destroyed the city of San Salvador broke down the rim of a small lake and drained it. The famous earthquake of New Madrid, Missouri, changed the level of the land to such an extent that a permanent swamp was formed in land that, before the shock, was high and dry. This area has since been known as the "Sunk Region." During the severest shock the current of the Mississippi is said to have been temporarily reversed; that it was greatly disturbed is shown by changes in its channel occurring at that time. Reelfoot Lake, in Tennessee, was considerably enlarged at the same time.

[11] Probably the most disastrous waves ever known to written history, however, followed this earthquake. After the town had been felled by shocks so terrific that thirty thousand people perished, most of the survivors took refuge on the massive sea-wall. Hardly had they reached it when the water began to recede, leaving the harbor dry. Then an enormous wave, sixty feet high, rolled in and completed the destruction, and thirty thousand more lives were swept out of existence before the waves ceased. At Cadiz the waves were thirty feet high, at Madeira eighteen, and along the Irish coast they were four or five feet in height.

[12] The sea-wave resulting from this earthquake crossed the Pacific Ocean and was recorded at Yokohama, Japan, twenty hours afterward. On the American coast the wave was observed as far north as Alaska, and to the westward as far as Australia. The earthquake that in 1854 devastated a part of Japan was followed by a destructive wave. At Simoda the wave was thirty feet high; at Peel's Island, one thousand miles away, it was fifteen feet; on the California coast it was from twelve to eighteen inches in height.

[13] The destruction of Babispe, a small village in northern Mexico, is an excellent illustration. This disturbance, alleged to be a volcanic eruption, was in reality nothing more than a severe earthquake that levelled the buildings of the town. During the series of shocks a fissure was made, extending several miles in length, and when equilibrium was restored, the fissure had be-

come a fault—one side or wall being, in places, from ten to fourteen feet below the other.

[14] At Monson, Massachusetts, the rock in the granite quarries usually exhibits signs of heavy strain. Professor Niles observed that pieces, before their ends had been detached, were split along a horizontal plane and bent upward at the middle. One mass, measuring 354 × 11 × 3 feet, increased an inch and one-half in length after it had been detached. These facts indicate the enormous pressure to which rocks may be subjected; incidentally they show that even the hardest rocks are decidedly elastic.

[15] An instrument for *measuring* any of the elements of an earthquake shock is called a *seismometer.*; if it merely *records* a shock it is a *seismograph.* The horizontal element of the shock is recorded by means of a delicate pendulum carrying a pencil or stylus. The jar sets the pendulum in vibration, and the pencil records the direction of the oscillations.

[16] The sudden formation of gases on their rapid motion from one part of the volcanic district to another, will account for earth shocks at such times.

[17] Of a total of 364 shocks, 147 occurred in the Atlantic Highlands and Coast Plain, 66 in the Great Central Plain, and 151 in the Pacific Highlands. These figures have only an approximate value, however, inasmuch as many of the earth shocks occurring in the sparsely settled regions of the Pacific Highlands escape notice altogether. Of 66 shocks recorded in Canada, the United States and the West Indies during one year, 24 were in the Atlantic slope and the West Indies; 3 were in the Great Central Plain; and 39 in the Pacific Highlands, including Mexico and Central America.

A MATURE RIVER LOOP: MOCCASIN BEND, TENNESSEE RIVER

The flood plain enclosed by the loop is rich farming land.

CHAPTER VII

THE WASTING OF THE LAND: THE WORK OF RIVERS

WHILE various forces are at work wrinkling and folding the strata of the rock envelope, other agents are constantly at work wearing away those same folds and irregularities and wasting or degrading the surface of the land to its lowest, or *base level.*

The principal agent in producing these effects is water, in one or another of its different forms. Falling on the land as rain it removes fine and loose particles of earth. It also sinks into the pores of the rock, perhaps dissolving some of it or, perhaps, freezing and breaking off small pieces. This process of degradation is called *erosion.* Gathering into swift torrents, the latter cut their channels deep into the surface, producing the effects called *corrosion.* Flowing against cliffs and banks or, perhaps, through underground channels, it saps the foundations of masses of earth and breaks them down by *undermining.*

Gravitation is an aid in the process of degradation, for not only does the water invariably flow downward, but the *detritus,* or rock waste resulting, is likewise moving to lower levels. Perhaps, for a time, it lodges in a hollow, or basin-shaped depression, until the latter is filled; then the downward progress again begins. Of the

water that falls from the clouds upon the land,[1] some evaporates and mingles with the air; a part sinks into the ground, filling up the underground channels and reservoirs; the remainder gathers into channels and flows back to the sea.

Streams of water flowing upon the land are variously

THE BEGINNING OF A LOOP, CUMBERLAND RIVER, KENTUCKY

The river has built a flood plain on the west side and is cutting into the east bank.

called rills, rivulets, brooks, creeks, and rivers—the name usually depending on the size of the stream. The largest streams are *rivers*. Almost every river is made up of branches and tributaries, and these, in turn, are fed by smaller branches—all together comprising the *river system*. The area drained by the river system is its *watershed*[2] or basin, and usually the latter is surrounded by a

well-defined height of land, the ridge or *divide* that separates it from adjacent basins.

In some instances the crest of a mountain-range forms a divide, but in very many cases the latter is an almost imperceptible rise only a few feet high.[3] Thus, at Chicago, the divide between Lake Michigan and a tributary of the Illinois River is only ten or fifteen feet higher than the level of the lake. It must be borne in mind, however, that a high mountain-range is not necessarily a divide, for there are many instances where ranges are crossed by rivers. From any good map find the divide between the Susquehanna and Allegheny Rivers; between the Great Kanawha and Ohio Rivers. Compare the divides with the ranges.

Physiography of Rivers.—The beginnings of most large rivers are high in the mountains, where the rainfall is heaviest and the greatest accumulation of snow is found. The water that is let loose from a spring or from a winter's snowdrift trickles down the slope in tiny rills. On their way the rills unite into rivulets and brooks that tumble down the mountain slopes in self-made, pebbled gullies.

Other streams join the brook and swell its volume into a mountain torrent that rushes down the steep incline, cutting its channel into hard rock and tossing to the one side or the other the obstacles in its way. Almost always it flows in a deep cañon or gorge, the cutting of which is the principal part of its work.[4] When the stream emerges from the mountain cañon it is burdened with rock waste brought from the mountain side and, no longer able to carry all of this, because of the lessened slope, it drops the coarser material, forming a fan-shaped pile. Thenceforth, because it is no longer a swift torrent, it cannot remove the heavier obstacles, but must flow around them.

The lighter rock waste, called *sediment* or *silt*,[5] is still carried by the flood of the river. Perhaps a little of it is dropped here and there, but the greater part is borne to the coast plain, which in many instances is the "made-land" formed of river sediments. After reaching the latter the silt is gradually dropped until the river reaches tide-water. There, about all the rest of the silt is deposited — either to be spread out in the form of a delta, or to be piled up near the shore in spits and bars.

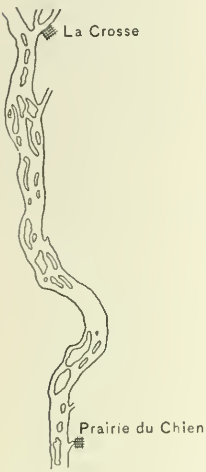
LOOPS AND CUT-OFFS OF THE LOWER MISSISSIPPI

The abandoned channels are sometimes called "Bayous;" they form an intricate net-work of passages.

It is evident, therefore, that in streams which are degrading the land three processes are usually going on, namely—corrasion and undermining, transportation, and deposition. That is, from the moment the water touches the rock envelope it is picking up particles of earth; it is carrying them downward; or else it is dropping them. Whichever it does, depends on the current. Increase its velocity and the water will pick up more particles; decrease the velocity and it will begin to drop them and flow around them. In the upper, or torrential part, most

streams emphasize their right of possession by cutting their channels deeper. In the lower course the reverse is apt to be true; the stream clogs its channel with silt[5] and is therefore compelled to make a new one on the one side or the other.

In the study of such rivers as the Mississippi the reasons therefor are not hard to find. Because the slope of the plain through which it flows decreases, the velocity of the current is checked, and because of the slackening current the water is constantly dropping its load of silt.[6] Moreover, when the latter has been dropped, the water cannot pick it up again unless the current is quickened, and must thereafter flow around it.

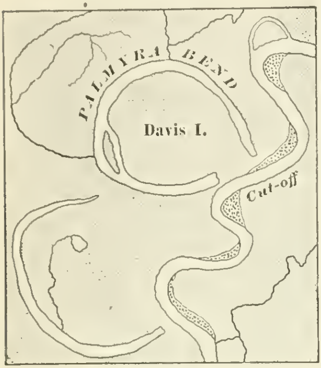


ISLANDS IN A RIVER

Islands are common in rivers carrying a considerable sediment. The anchoring of a snag, or any other obstacle, slackens the current and causes the deposition of silt. The latter increases in amount until finally it reaches to the surface. Then vegetation gets root and an island results.

The river which flows over a decreasing slope has a tendency, therefore, to form loops in its lower course, and in general the loops are long-lived. But when there is a succession of years of increased volume of water, the conditions are changed. Because the volume of water is increased the current is quickened, and the water then begins to pick up silt that it had previously dropped. In time, the neck of the loop is cut away, and the river shortens its channel — sometimes by twenty or thirty miles.[7] The line of *moats*, or oxbow lakes, along the lower

Mississippi marks the old loops and abandoned channels along this river. It is evident also that the great amount of silt removed when a loop is destroyed must be carried farther down stream and there deposited. How would this affect the river so far as the formation of bars is concerned? As a matter of fact the destruction of a loop is attended by changes in the channel that are noticeable many miles both above and below the loop; and more than a year elapsed after Davis cut-off had formed before the changes ceased.



PALMYRA BEND—NOW PALMYRA LAKE

If, during a period of several years, there is less than the usual rainfall, the stream will probably increase the amplitude of its loops, and even make new ones. With the coming of successive years of greater rainfall, however, the volume of water is increased, the current is quickened, and the water begins to pick up and remove sediment that formerly it had been unable to carry.

Growth and Development of Rivers.—A river and its basin do not constitute a fixed, unchanging feature of the land. On the contrary, every river passes through the various stages of infancy, maturity, and old age; and its legitimate work is to carve away and remove its basin until every part is worn away to base level. The moment any plain or surface—such, for instance, as the coast plain of New Jersey—is exposed to the action of the weather, the water falling upon it begins to form channels[8] and flow to the sea. Such a stream may be called an infant river.

At first the stream drains its water-shed very imperfectly. It encounters many obstacles; and if the slope is gentle, it finds not a little difficulty in making its channel. It is embarrassed by the inequalities of the surface, and because of them, lakes and swamps form in the slight depressions. The channels are apt to be shallow and the divides between the adjacent branches are neither permanent nor well defined. In consequence, any unusual flood may result in the abandonment of an old and the selection of a new channel. Red River of the North, is an example of an infant river.

THE LEGITIMATE WORK OF A RIVER

It removes the rock waste from A to B: A B, the old; a' b', the new profile.

As a stream reaches maturity its character is changed. The channel is deepened and cut nearer to base level. The gullies of the tributary streams become ravines and many of the latter are sculptured into broad valleys. The tributaries extend their channels backward and not infrequently capture the waters of other streams less vigorous (*See illustration, p. 113*). The mature stage is the age of its greatest vigor and power. It may lengthen itself at both ends; it may build a delta at its mouth and extend the latter seaward, or it may cut its headwater channels backwards.

INFANT STAGE OF A RIVER

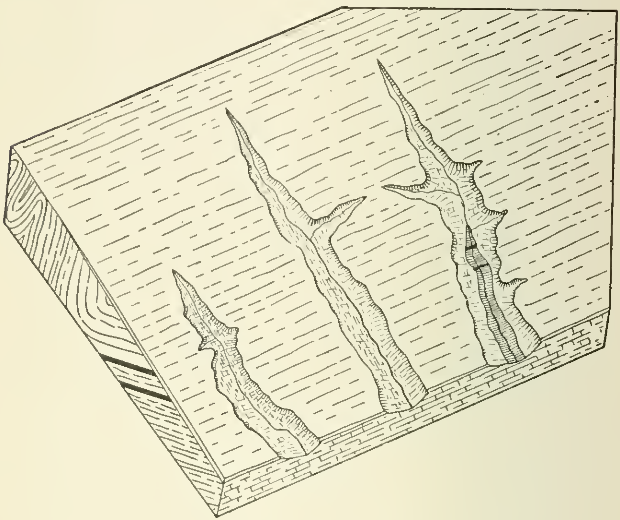
The stream has notched its channel in the plain A B

The old age begins when the river has cut away and transported all the available material within the reach of its various branches. Thereafter it can be revived only by a gradual elevation of some part of its bed, by changes in

THE MATURE AND SENILE STAGES OF A RIVER

The main stream and its tributaries have carved deep channels in the plain A B: In a' b' c' the remaining material has been carried away.

its slope, or by a considerable increase of its volume. Just as a log moved against the saw results in cutting the timber, so a gradual uplift of the stream channel gives the river fresh power and, for a time, rejuvenates it. An increase in the volume, by quickening the current of the stream, has also a similar effect. If, as in the case of the



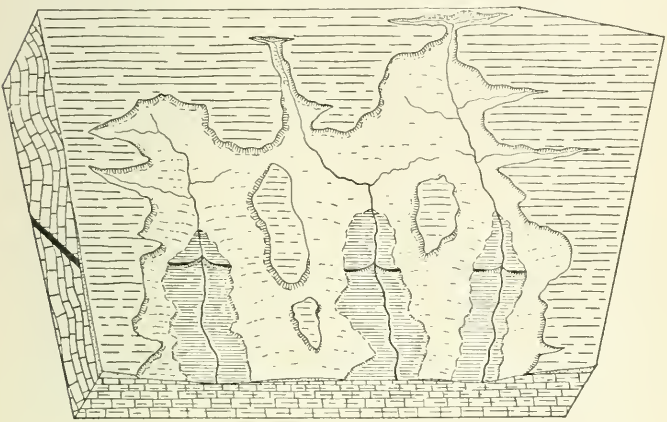
YOUNG RIVERS

The stream on the right has uncovered the ledges of hard rock shown in the margin and falls have resulted.

uplift of Uinta Mountains across Green River, the elevation is long-continued, just so long will the river be actively at work at that point. It can be rejuvenated along its whole course by the uplift or tilting of its watershed in such a manner as to increase the current along the whole extent. Uplift is nearly always followed by extensive stream corrosion.

Flood-Plains.—It often happens that a stream removes more material from its upper or torrential part than it can conveniently carry. The excess is then spread over the middle and lower parts of the basin, forming the "bottom lands" or *flood-plain.*

The deposition of sediment is the result of a slackening



MATURE RIVERS

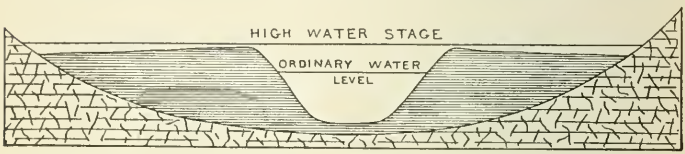
The greater part of the basin of each has been removed. The tributary of the central stream is carving its way into the basin of the river on the right and will eventually absorb the head waters of the latter.

of the current. In its infant stage the river has but little cutting power and usually can carry all the material it removes. When the headwater streams acquire greater vigor, however, they remove so much rock waste that in the middle and lower courses the water is overburdened with it, and the process of flood plain-making begins.

Along that part of the plain occupied by the stream, unless the current is increased, the deposition of sediment is constantly going on. The river builds its bed and banks a little higher than the level on either side, continuing the

process until the coming of high water; then it breaks through its self-made banks and selects a new channel in lower land. By this process of adjustment, the river, in turn, may occupy every part of its flood-plain. It therefore follows that flood-plains are due to the overburdening of the current of the stream.

In its relation to life and its industries, the flood-plain is the most important part of river physiography. The surface is always level, making the region accessible to transportation. Moreover, the rock waste is mixed with the elements that form the food of plant life, and therefore the flood plain has a most fertile soil. In the Mississippi



A FLOOD PLAIN

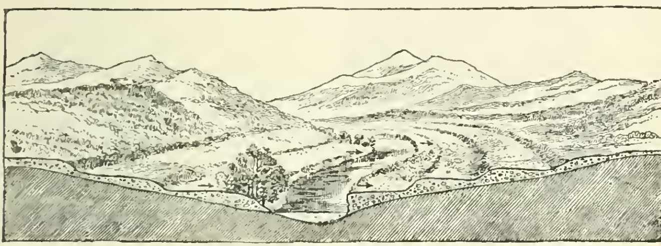
The dark shading represents the sediment deposited by floods.

Valley, for instance, where the bluff lands produce twenty bushels of wheat, the bottom lands yield thirty; and if an acre of bluff soil yields one bale of cotton, the same area of bottom lands yields two. The greater part of the Chile of geography is a simoom-swept desert with scarcely a sign of life excepting that which pertains to the mines and the mountain valleys. The real Chile is found in the densely-peopled flood plains of the Andine streams. In these short valleys are concentrated nearly all the activities that go to make a great state.

Neither do we find the Egypt of history in the broad stretch of land lying between the Red Sea and the Libyan Desert. On the contrary, the four thousand years of history that has given to the world so much that goes to

make up modern civilization, belongs to the flood plain of the Nile. What has been the effect of the Mesopotamia on the history of the East?

Terraces.—After a river has cleared away all the rock-waste and silt it can reach at the headwaters, the stream may then turn its cutting power against its flood-plain. Instead of depositing sediment, the water begins to remove it. So it forms a deeper channel, along the sides of which a new and lower flood-plain is built. The new flood plain with the remnant of the old one form *terraces*. Of these there may be three or even four. Ultimately, however, nearly or quite all the flood-plain is removed.



TERRACES IN A FLOOD-PLAIN

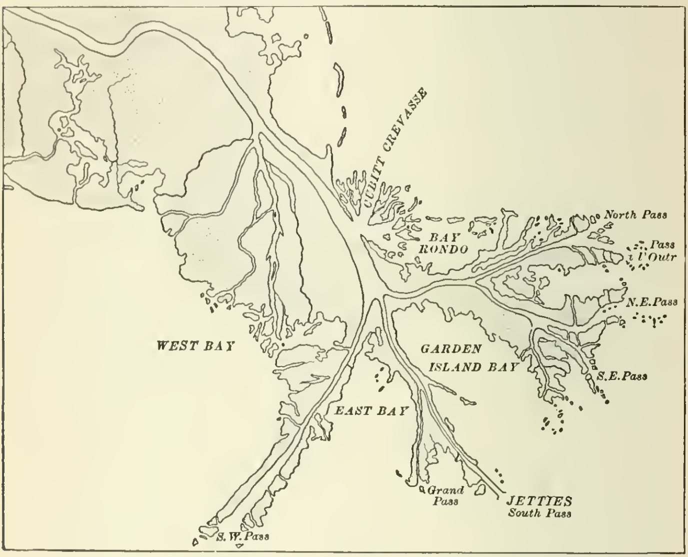
Each marks a stage of down-cutting. The darker shading shows the old bed of the river.

It is evident, therefore, that flood-plains and terraces are merely incidents in the history of a river. Perhaps most of the rivers of the United States are in the flood-plain stage of their existence. Many of the streams of the northeastern part are in the terrace stage and are approaching the period of old age.

Deltas and Estuaries.—Salt water has a very remarkable effect in clearing muddy, fresh water, and the moment the two mix the remaining silt held in suspension is quickly deposited. It follows, therefore, that, unless the sediment is swept away by currents and tides, a

considerable accumulation will form at the mouth of the river.

The accompanying figure, the delta of the Mississippi River, shows one of the most interesting types of delta formation. It is evident, in this case at least, that the banks of the delta are self-made, and that they have been formed because the current has been checked more effectually at



A DELTA MOUTH: THE DELTA OF THE MISSISSIPPI RIVER

the edges than in mid-stream. It is also evident that since the lower Mississippi has occupied its present channel, the river has built its lower part nearly one hundred miles into the Gulf of Mexico.

The deltas of the Volga, and Ganges-Brahmaputra are considerably more intricate than that of the Mississippi. They are likewise older, and therefore more compactly

filled with sediment. The delta of the Ganges-Brahmaputra is perhaps the most extensive known. Its frontage on the Indian Ocean is about two hundred miles, and its area about twice that of the State of Texas. Much of the land consists of shifting mud-flats, and the whole region is subject to destructive inundations.

The delta of the Adige-Po has developed in a manner not unlike that of the Ganges. Probably no other river of its size in the world brings down more sediment than the Po. As a result its delta is filling and extending very rapidly—so rapidly, in fact, that the town of Adria (Hadria), in Julius Cæsar's time a seaport, is now more than twenty miles inland. Ostia, in early historic times, at the mouth of the Tiber, is now about seven miles inland.

With respect to economic value, delta lands surpass almost all others in the possibilities of productivity. The soil is exceedingly rich, and, because of the constant additions from the river, it is enriched as fast as its nutritive elements are taken up by vegetation. The Nile delta has long been known as the granary of Egypt—the Sunderbunds of the Ganges-Brahmaputra are foremost among the great rice-producing fields of the world.

CHESAPEAKE BAY: AN ESTUARY, OR SUBMERGED RIVER MOUTH

A part of a comparatively level plain has subsided below sea level.

An inspection of any good map will disclose the fact that while some rivers reach the sea, each through a delta, others equally powerful with

respect to current, flow into estuaries. The Mississippi and the Delaware are contrasting examples. In the former case the river has a tendency to block its mouth with silt; in the latter, a downward movement, or sinking of the coast has practically drowned the mouth of the river. Moreover, the action of the tide is usually strong enough to keep the channel clear of silt between

A FJORD MOUTH OF A RIVER

Its situation adapts it for the centre of commerce of a newly-settled region.

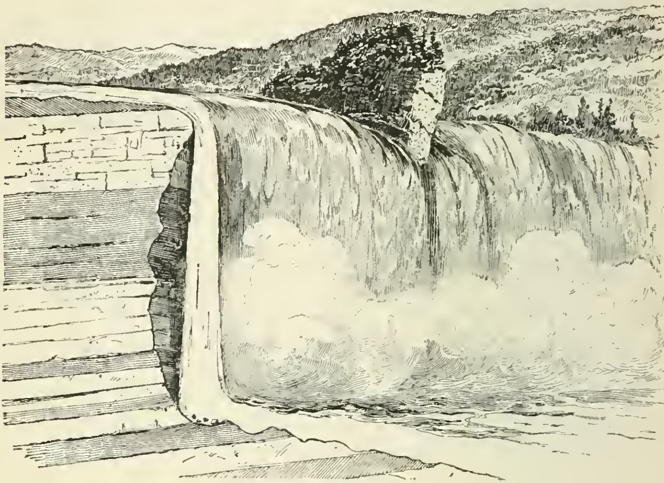
bars. So, between the scouring action of the tide and the sinking of the valley there is not only a broad, but a deep area of water in most estuaries. If the mouth of the river is in a coast plain, the estuary usually takes the form similar to that of Delaware River. Along a rugged coast with an abrupt slope, however, the estuaries more commonly are like the indentations of the Maine coast. They are also numerous along the coast of Norway, where they are called *fjords*.

In rivers that flow into estuaries, the sediment is deposited in the form of *bars*. In most instances two bars are formed, one at the mouth, the other at the head of the estuary. The reason for this double deposition of sediment may be found in the action of the tides. Bars are formed in comparatively still water, so, when the tide is slack at flood, the deposition takes place at the head of the estuary where the salt and the fresh water meet; when the tide is ebb, the two waters meet at the mouth of the estuary and the deposition of sediment takes place at the lower end.

It is evident that the estuary favors commerce and navigation while the delta on the whole is a hindrance. In the case of the Mississippi, the navigable channel of the delta has been kept open at an enormous expense. Of the great seaports that are centres of commerce, by far the greater number are on the shores of estuaries.

Cascades and Rapids.—In flowing to lower levels, if the slope is abrupt, the water descends in a series of rapids in the form of *reaches* more or less terraced. The streams of the New England Plateau, and to a greater degree the torrents of mountainous regions are illustrations. In some instances, however, the stream plunges over a vertical embankment in the form of a *cascade* or *fall*. Of these, Niagara Falls, Spokane Falls, and those of the Zambesi River are illustrations. In some instances mountain streams make tremendous leaps. In the Yosemite Valley, Merced River in three plunges falls 2,600 feet; and Bridal Veil fall, with a sheer pitch of 1,500 feet, reaches the lower level in the form of fine water dust. The Staubbach ("brook dust") of the Alps is a similar cascade, having a fall of 900 feet. The Cascade Range of the United States and the Lauterbrunnen ("nothing but fountains") of Alpine Europe are names that suggest the character of these regions.

In some instances the stream has had little to do with making the cliffs over which it falls; in other cases, however, the river itself has made the falls. If a stream flows over the edge of a hard layer that rests on a softer material, the latter will be more quickly removed; moreover, as the softer layer is worn away, the fall becomes greater and the water acquires an increased cutting power because it has a constantly increasing distance to fall. Finally the stream



SECTION OF A WATERFALL

The stratum at the top of the fall is harder and more resistant than the strata below.

cuts away so much material at the lower level that a cataract results.

In this manner the falls of Niagara River were formed. There is an upper layer of hard limestone surmounting a deep layer of softer rock. The upper layer offers considerable resistance to the water; the lower layer is easily cut away. Hence the falls are increasing rather than decreasing in height. The upper layer, however, is worn not a

little, and the falls are receding up stream at the rate of nearly two and one-half feet a year.[10]

There are many cataracts, however, that are the result of accident. Thus, a flow of lava across Columbia River dammed the channel and formed the well-known cascades. A similar lava flood at the same time obstructed its chief tributary, the Willamette River, forming the cataract at Oregon City.

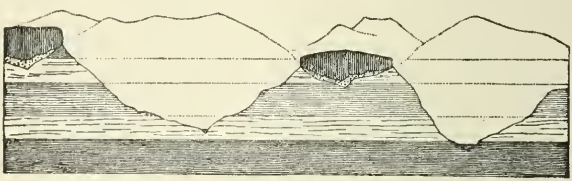
Falls and rapids frequently occur in the terrace stage of rivers, although they may be developed in early maturity. They are rarely found in the flood-plain age, because the flood-plain buries all inequalities. After the stream has carved away its flood-plain, it may uncover and develop its former rapids and cascades.

Migration of Divides.—As a rule, every stream works most actively in the upper or mountain part where its current is swiftest. As the various headwater streams deepen their gullies they frequently extend them to a considerable distance backward; and a very vigorous stream may even cut its channel backward across a ridge or height of land. The latter then ceases to be the water-parting; the divide therefore "migrates" or recedes from its former position.

In cutting its channel backward across a ridge or height of land a stream sometimes captures and diverts a part of the feebler stream flowing on the opposite side of the channel (*See illustration, p. 113*). Many of the "wind gaps" of the Appalachian region are the results of this sort of river piracy. They are abandoned stream channels—abandoned because the former occupant of each has been captured further up the valley by a more vigorous stream that has crossed the height of land to get it. The Vistula River has probably obtained several of its headwater streams by the robbery of a neighbor, and at least one

stream in Northwestern Ohio and several in Pennsylvania seem to have suffered in a similar way.

Unusual Adjustments.—In selecting a new channel or in adapting itself to the changing conditions of an old one a river is said to *adjust* itself. There are several causes which may compel a stream to change its course. It may clog its channel, or the latter may be obstructed by accident. Thus, by long-continued silting, the Hoang River, "China's sorrow," built its channel higher than the divide, near the top of which it flowed. In 1852, during a season of high floods, the river broke through its banks. Before that time it had flowed southeasterly from



TUOLUMNE RIVER, CALIFORNIA

The old stream channel is under the lava cap which forms Table Mountain: the present channels are at the base of the mesa.

Kaifong into the delta of the Yangtze; after the break its course lay in a northeasterly direction and the river now flows into the Gulf of Pechili.

The flood of lava that formed the plains of the Columbia buried beneath it a long stretch of the river basin, and the river made a new channel around the lava flood.[11] Tuolumne River, California, was similarly buried, but finally succeeded in making another channel through the obstruction. It is not unlikely that Saskatchewan River was cut in two by the rise of a height of land across its course, the water being ponded in Lake Winnipeg and then overflowing into Hudson Bay.

Indirectly, man is responsible for the abnormal conduct

of certain rivers, and the cause thereof is the cultivation of the land. In order to make his land productive the farmer must not only clear it of growing timber and destroy the smaller vegetation, but he must also, in many instances, provide a system of rapid drainage. Because forestry, shrubbery, and sod all serve to retain water in the soil they therefore prevent rapid drainage. The removal of vegetation, on the contrary, has exactly the opposite effect. The rainfall is rapidly collected by the tributaries, and as quickly poured into the main stream. As a result, high and quickly-forming floods occur.

The Ohio and the Susquehanna, especially in late years, have suffered much from disastrous floods, and these are mainly the result of deforesting their basins. Wooded and grass-covered slopes are slowly drained; denuded slopes favor rapid accumulation of drainage waters.

Geographical Distribution of Rivers. — Rivers are the offspring of rainfall and, as a rule, regions of great rainfall are regions in which rivers are largest and most numerous. This is shown in the case of the Amazon and the Kongo. Both rivers are situated within the belt of almost constant rains. Each has a large number of powerful tributaries, and each discharges an enormous quantity of water.

A river cannot develop great length and size unless the water-shed that it drains has also a great superficial extent. When Columbus entered the mouth of the Orinoco, he at once declared the country southward to be a continent, for the reason that so large a river could not exist on a small body of land.

There is no apparent law governing the distribution of rivers except the position of slopes and the amount of rainfall. The largest rivers are not in the largest continents, nor are the longest streams in regions of greatest

rainfall. The Atlantic receives the waters of more large streams than any other ocean; the Arctic Ocean is the next in order. The reason therefor is the fact that the largest plains slope toward the one or the other of these two oceans.

The great plains and slopes of the Western Continent receive the full benefit of moisture-laden winds; and the rivers, as a rule, reach a higher state of development than those of the Eastern Continent. The Mississippi and the Amazon drain each a water-shed half as large as Europe. The Mackenzie, La Plata, Yukon, Columbia, and Colorado about equal in size the great master streams of the Old World.

The broadest part of South America is crossed by an almost constant rain belt, and therefore is in the region of heaviest rains. The ocean winds traverse a sweep of about 2,500 miles before they are arrested by the Andes Mountains; and because precipitation covers such an enormous area, there necessarily results a stream of vast proportions. As a matter of fact the Amazon discharges a greater volume of water than any other known river.

The chief plain of the Old World faces the Arctic Ocean. It is the largest plain in the world, and is drained by large rivers. None of them equals the Amazon nor the Mississippi-Missouri, however, for the reason that they are situated in a region of very moderate rainfall.

The southern part of Europe does not extend into the region of tropical rains; hence the absence of large streams on the southern slope. The southern part of Asia is under the tropical rainbelt, but the drainage slope is comparatively short, and but few large streams have formed. Thus it may be seen that the large plain of Eurasia is unfavorably situated for large rivers, while, on the other hand, the favorably situated areas are too small for the

development of great streams. The great number of smaller rivers, moreover, compensates for the absence of such rivers as the Amazon.

Africa possesses several large rivers, two of which, the Kongo and the Nile, are of considerable interest. The Kongo, like the Amazon, is an equatorial stream, and the behavior of the two is almost identical. The Kongo is smaller only because its basin is smaller. The Nile is remarkable for its annual overflows, and from the fact that, in the lower 1,200 miles of its course it receives not a single tributary.

Australia possesses but few permanent streams, and these are of small size. This continent is unfortunately situated. It is under the Calms of Capricorn, and it contains no high mountain range. The Murray-Darling is the only river of importance. In the summer season most of the streams disappear altogether, or else form a succession of shallow pools.

Continental Rivers.—There are several large areas that have no drainage to the sea, and the rivers are therefore called *continental rivers*. Where is the continental region of Eurasia? It is drained by a multitude of rivers; name the four largest. In Africa the only large continental rivers are those flowing into Lake Chad. There are many continental rivers in Australia. Practically all of them are dry in summer and some are filled only when an occasional cloud-burst pours a flood of water into their channels.

The Humboldt, Carson, and Jordan are the principal continental streams of North America. Describe their situation from any convenient map. What do they indicate with reference to rainfall? What would be the probable effect on these rivers if the Sierra Nevada ranges were no higher than the Appalachian Mountains? In South

America the Desaguadero, the outlet of Lake Titicaca, is the principal continental stream, although one or two of the larger rivers in Argentina are occasionally cut off from the sea.

Economic Importance of Rivers.—Rivers are the most important highways of commerce and, in many ways, are the lines along which civilization and settlement penetrate to the interior of a country. Even at the present time merchandise can be carried by means of river navigation for less than the cost of transporting it in any other way. Most of the great migrations of peoples have followed the lines of rivers, and in mountainous regions the cultivated areas are confined mainly to river valleys. Outside the Great Central Plain of the United States most of the railways of the country have been built along river valleys, so that these are practically "lines of least resistance" to the activities of a people.

QUESTIONS AND EXERCISES.—Under what conditions and at what times is the stream with which you are best acquainted muddy?

Note and describe any place at which the stream is cutting away its banks.

Note and describe some place where sediment is being deposited. If possible, account for the action in each case.

An embankment of freshly turned earth receives the full force of a rainfall; how will its general form most likely be affected?

What effect has sod, shrubbery, and forestry on a surface that is exposed to rain?

Name some results that might occur if the channel of a stream were blocked?

How would the Mississippi be affected if the Ozark highlands were elevated considerably higher? (*See any good topographic model or relief map.*)

What effect will the approaching old age of the Mississippi have on the size of the Gulf of Mexico?

On p. 113 is a map of Chesapeake Bay; make a sketch-map and restore the river channels on the supposition that the surface were uplifted until about the lowest point is higher than sea level.

Does the appearance of the Cañon of the Colorado River suggest an abundant or a scanty rainfall? How would a great increase in the rainfall affect the scenery so far as the topography of the valley is concerned?

What does the absence of tributaries indicate concerning the rainfall of the lower Nile?

From the cyclopædia, or any convenient reference-book obtain a description of the Volga and its delta.

Make a list of ten or more important cities situated on estuary mouths;—two on or near delta mouths.

COLLATERAL READING.

SHALER.—Aspects of the Earth, pp. 143–196.

MILL.—Realm of Nature, pp. 241–251.

DAVIS.—Rivers of New Jersey. *National Geographical Magazine.*

REDWAY.—Physiographic Geography of the Mississippi River. *Proceedings Engineers' Club, Philadelphia.*

MISSISSIPPI RIVER COMMISSION.—Map of the Alluvial Valley of the Mississippi River.

POWELL.—Physiography of the United States, Monograph II.

RUSSELL.—Rivers of North America.

NOTES.

[1] On an average, about three feet of water fall each year on the land. The rate is not uniform, however, but varies from a fraction of an inch to about fifty feet. Directly and indirectly *all* the water of the land comes from the sea and, sooner or later, returns thereto.

[2] The term "water-shed" is often used as a synonym of "divide." Properly used, however, it is not a divide but a basin.

[3] There are a few instances in which the divide is so ill-defined that the same pool, pond, swamp, or stream may discharge its waters into streams whose mouths are at a great distance one from the other. Thus, Two-ocean Pond, in Yellowstone National Park, in high-water season, has two outlets—one through the Yellowstone to the Mississippi, the other through the Columbia.

In other words one has Atlantic, the other Pacific drainage. The Cassiquiare River bifurcates, discharging simultaneously into the Orinoco and the Rio Negro, a tributary of the Amazon. Between the headwaters of the Parana, and those of the southern tributaries of the Amazon, the land is so flat that, in places, the drainage is undecided.

[4] The cutting and the carrying power of water depends on the speed of the current. A slight difference in the velocity makes a very great difference in its carrying power. Water flowing at the rate of four miles an hour will carry *sixty-four* times as much material as water flowing at half that rate of speed ; that is, the carrying power varies inversely as the sixth power of the velocity.

[5] Silt is the name commonly given to matter held in suspension in water ; sediment to material that has been dropped. The two words are often interchangeably used.

[6] Whichever process goes on at any particular locality depends on the velocity of the current. In seasons of high water the current may remove material, while at low-water stage it may form a bar. That is, the middle course of a stream extends much further down stream in high than in low water periods. In short streams that flow in channels of considerable slope there is practically but one course. In rivers whose waters are habitually clear the "courses" are rarely ever well defined.

[7] Davis cut-off at Palmyra bend, near Vicksburg, Mississippi, is an example. The distance around the loop was twenty-two miles ; across the neck, it was scarcely half a mile. An obstruction anchoring in mid-channel forced the current against the narrow neck, and the latter, little by little, was cut away by the stream. Finally the isthmus was severed and the whole flood of the river very quickly poured through the cut. Around the loop the fall of the river was about four inches per mile ; through the cut, over five feet. The river scoured its channel about one hundred feet in depth, and so swift was the current that more than a week elapsed before steamboats could ascend it. The effect of the cut-off was far-reaching, and extended both above and below Palmyra Bend a distance of over one hundred miles.

[8] Such a stream is sometimes called a *consequent* river because its formation is consequent upon the elevation of the plain. A river is an *antecedent* stream when its existence dates before that of some other feature. Thus Green River existed before the forma-

tion of Uinta Mountains, and with respect to them is an antecedent river.

[9] At the present time the real mouth of the Hudson is near Troy. Below this point the river is an arm of the sea, swept by tides throughout the whole distance. This singular condition is due to the fact that the lower part of the river has been submerged, since Glacial times. The explorations of the U. S. Coast Survey have disclosed the old channel of Hudson River from lower New York Bay a distance of nearly eighty miles to the southeast. Were this part of Atlantic coast again to be raised, it is not unlikely that the river would recover its long-buried channel.

[10] At the point where the angle in the ledge is formed, the recession since 1875 has been more than two hundred feet; at the American Fall, since 1842, it has been very slight. It is a question of time only until the Canadian Fall shall have receded to a line between Dufferin and Sister Islands. When this has taken place the American Fall will have nearly or quite disappeared. Had the conditions of a hard stratum at the top and a softer one at the bottom been reversed, there would now be no cataract, even had there been one at the beginning of the present epoch. The softer rock would have been worn away until the perpendicular front had become an incline extending to a point below Whirlpool Rapids; and instead of the sublime cataract, there would now be a succession of rapids like those which mark the passage of St. Lawrence River.

[11] In several other localities the Columbia has cut its channel through similar obstructions. In at least one case the river reclaimed its former channel by cutting through the entire thickness of lava, to a depth of about 2,500 feet; at the two "cascades" the river is attempting to cut its channel through coulées of lava that flowed across its channel. Deschutes River, a tributary of the Columbia, is readjusting itself by cutting a new channel into the same sheet of lava.


180° 150° Longitude 120° West from 90° Greenwich 60° 30°
Lincoln Sea
ARCTIC
OCEAN
Kane Sea
Baffin Bay
GREENLAND
Davis Strait
ASIA
ARCTIC CIRCLE
ICELA
Hudson Bay
Bering Sea
BRITISH ISLES
NORTH AMERICA
VANCOUVER I.
AZORES
ATLANTIC
BERMUDA IS.
Gulf of Mexico
WEST INDIES
TROPIC OF CANCER
HAWAII
Caribbean Sea
PACIFIC
OCEAN
EQUATOR
OCEAN
SOUTH AMERICA
FIJI IS.
TROPIC OF CAPRICORN
NEW ZEALAND
FALKLAND IS.
RIVER
AND D
ANTARCTIC OCEAN
180° 150° Longitude 120° West from 90° Greenwich 60° 30°


30°
60° Longitude 90° East from 120° Greenwich 150°
180°
FRANZ JOSEF LAND
SPITZBERGEN
NOVA ZEMBLA
A R C T I C
O C E A N
Kara Sea
Gulf of Obi
Lena Delta
ARCTIC CIRCLE
E U R O P E
A S I A
Black Sea
Caspian Sea
Aral Sea
Okhotsk Sea
Bering Sea
Japan Sea
Yellow Sea
P A C I F I C
TROPIC OF CANCER
O C E A N
Arabian Sea
Bay of Bengal
CEYLON
China Sea
PHILIPPINE IS.
EQUATOR
I N D I A N
O C E A N
MADAGASCAR
TROPIC OF CAPRICORN
O C E A N I C A
FIJI IS.
AUSTRALIA
TASMANIA
NEW ZEALAND
ANTARCTIC OCEAN
EMS
E.
80°
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60° Longitude 90° East from 120° Greenwich 150°
180°

CHAPTER VIII

THE WASTING OF THE LAND: THE WORK OF UNDERGROUND WATERS

PROBABLY almost as much water sinks into the porous rock and the innumerable crevices of the rock-envelope as gathers in the various external channels. The work of telluric, or underground waters may not be quite so active in degrading the rock envelope as are the surface streams, but they are nevertheless important factors in the physiographic processes that shape the earth's topography. Surface streams flow quickly away in their channels, but the underground waters must trickle slowly through channels that are ill-adapted, spending their energy not only in forcing their way through passages that perhaps are self-made, but also in keeping the passages clear of obstructions. The work of surface waters, therefore, is comparatively easy and simple; that of underground drainage is vastly more difficult.

If the prevailing rock of a region be mainly of clay, or slate, or other impervious rock, the underground drainage will be close to the surface,[1] for such rocks not only prevent the passage of water, but they are also insoluble. In such cases the water must trickle through the top soil much in the same way that water passes through a filter made of sand and gravel—that is, it must flow in the spaces between the particles of rock waste.

On the other hand, if the rock of a region is mainly of limestone, and more especially if the strata be broken and

faulted,[2] underground drainage is apt to be very extensive. Not only does the water clear a passage for itself along the lines where the rock is broken, but it also dissolves enough of the limestone to make caverns of vast extent.

It must not be assumed, however, that these waters always remain underground. On the contrary, they are constantly in motion, and they finally emerge from their channels to reach the surface. In the study of underground waters they may be considered of three kinds, namely—*percolating waters*, *springs* and *artesian wells*, and *underground streams*.

Percolating Waters.—When water sinks into porous ground it fills the spaces between the grains of sand, gravel,

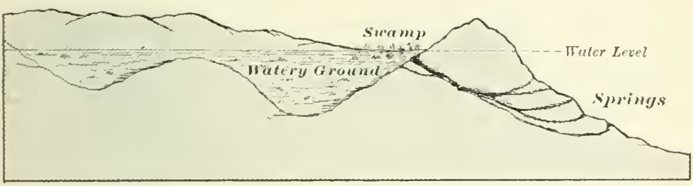


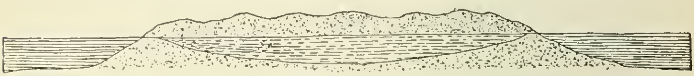
DIAGRAM SHOWING THE FLOW OF PERCOLATING WATERS

or other soil. Some soils are so porous that a cubic foot will contain more than one-quarter of its bulk of water. The latter sinks through the ground until it meets a layer of rock or clay through which it cannot pass. It therefore accumulates until its level is as high as the rim of the impervious stratum.

Flowing over the lowest part of this rim, it goes on, perhaps to fill a similar basin lower down the slope, or possibly it comes to the surface in the form of a swamp, a pond, or a lake. If the plain or slope is traversed by a river valley a great deal of the water oozes through the soil into the stream. In many instances waters of percolation are the chief supplies of streams.[3]

Wells are always filled by percolating waters, and to obtain an abundant supply it is necessary only to sink a shaft to some point below the level of the water. Unless the well is so shallow as to catch the surface drainage, the water is usually cold and wholesome. The water of shallow wells is apt to be impure.

If the area of porous soil is large and has a considerable depth, an enormous quantity of water may be held. The City of London, with its six millions of people, is supplied with water that percolates through the adjacent chalk-beds, and the water supplies of many of the towns and villages of the high plains east of the Rocky Mountains are derived in a similar manner.



THE WATER SUPPLY OF LOW SANDY ISLANDS

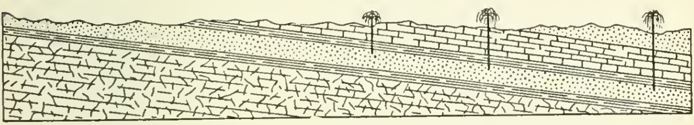
The lighter fresh water rests on the sea water.

The "sand valleys" of Western Kansas, Nebraska, and Dakota furnish an excellent example of percolating waters.[4] The storm waters falling in these valleys are almost all absorbed and held in suspension by the deep deposits of light, pulverulent rock waste. During dry seasons the waters of these reservoirs are about the only supply to the people living in that region. The amount thus held in the porous rock waste is generally sufficient to irrigate the crops that otherwise would perish from drought.

The water supply of small and low islands is obtained in a similar manner. The storm waters fall on the island and immediately sink into the sand until they reach salt water. But inasmuch as the fresh water is the lighter of the two, it rests upon the surface of the salt water without mixing with the latter.

In many instances the underground waters are confined between inclined strata of impervious rock. In such a case, if the porous layer be tapped by a boring, the water is forced up through the shaft to its normal level. Artificial springs of this character are called *artesian wells.* The "driven" or "piped" wells so common throughout the Mississippi Valley and the prairie region are examples of such wells. They are shallow, however, and tap only the superficial percolating waters. The water, moreover, is usually brought to the surface by ordinary lifting pumps; it is very rare that such wells are "spouters."

In the case of wells sunk to a depth of two thousand feet or more, the water in many instances is thought to



THE WATER SUPPLY OF ARTESIAN WELLS

The porous stratum is both covered and underlaid with impervious rock.

be forced above the surface—not by gravity, as is commonly supposed, but by the pressure of the air or other gases within the reservoirs.

Along the low coast plain of Southern California several hundred shallow artesian wells have been driven, and many acres have been made productive. The first wells were spouters, but at present, in nearly every instance the water must be pumped to the surface. Many such wells have been bored in the Sahara.[5]

Springs.—A small stream of water issuing from the ground is called a *spring.* In some cases the water spurts from a sloping wall, such as the face of a cliff, but in general, it gushes out of comparatively level ground near the

foot of a slope. Usually the discharge does not amount to more than a few gallons per minute, but in a few instances it is sufficient to fill the channel of a good-sized stream.[6]

The storm waters that fall on porous soil sink until they come to rock through which they cannot pass, and, flowing along the surface of this impervious layer, finally emerge to the surface at some distance lower down. In the meantime, if the water has been able to make a free channel instead of slowly percolating through the ground, it becomes a spring.

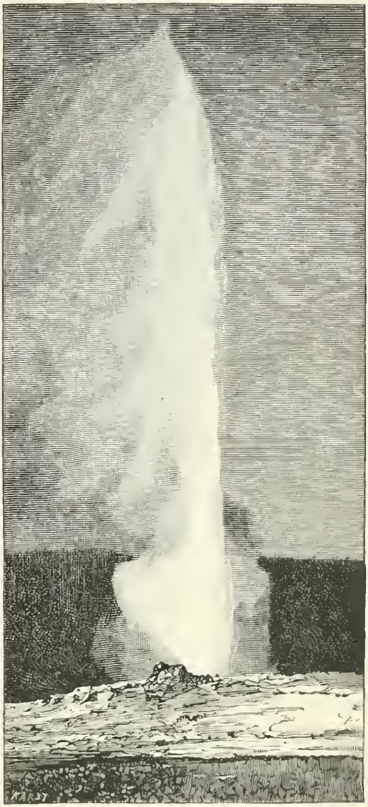
As a rule every spring makes its own channel. Usually the force of the flowing water is sufficient to carry away the lighter and finer material, thereby not only forcing a passage, but keeping it clear afterward; but in many cases the water makes a channel by dissolving a part of the rock through which it flows. If the quantity of material dissolved be considerable, *mineral springs* result. Such springs are very common. Those at Saratoga, Vichy, and Carlsbad, are known all over the civilized world.

In volcanic regions, where the rocks are apt to be seamed with fissures, the water trickles downward until it comes in contact with heated rocks, and when it again emerges to the surface the water may be at a boiling temperature.

So long as the mouth of a spring is lower than the surface of the waters from which it is derived, the spring will continue to flow, and will be a *constant* spring. If it be situated in a region of periodical rains it is apt to be a *periodical spring*—flowing during the rainy season only. If the flow depends partly on the pressure of air or other gases, an intermittent spring may be formed.[7]

Geysers.—In several volcanic regions there are hot springs, which at intervals eject copious quantities of hot water and steam. The eruptions, unlike volcanic outbursts, occur with almost clock-like regularity.

The geyser differs from other hot springs in having a long, irregular tube that extends deep into hot volcanic rocks. The tube is formed probably by the spring water itself, which, when very hot, dissolves a considerable amount of the mineral silica but deposits it on cooling.



A GEYSER, YELLOWSTONE NATIONAL PARK

The water that gradually collects in the lower part of the tube in time is heated far beyond the temperature at which water ordinarily boils. For a considerable time, the weight of the water in the upper part of the tube prevents boiling in the lower part. Finally a small amount of steam is formed, and some of the water is forced out at the top of the spring. As soon as this occurs, the pressure at the lower part being relieved, the water below, that has been heated far above the boiling point, flashes into steam — not gradually but instantly.

Eruptive springs of this character are not common, and there are but three regions known in which they have been found—Iceland, Yellowstone National Park, and Northern New Zealand. Hot mineral springs occur in many other

localities, but they are not eruptive. The geyser region of Iceland has been known for more than a century. It is situated near the group of active volcanoes and covers an area of two or three square miles. There are about one hundred eruptive springs, one of which, Grand Geyser, spouts a column of water and steam to a height of one hundred and forty feet. The New Zealand group is situated near the volcano Tarawera. It is small in area, and contains but few spouting springs.

The geyser region of the Yellowstone National Park, Wyoming, contains several groups, mainly in the basin of Firehole River. It comprises more than ten thousand geysers and hot springs. Of this number about two score discharge water to a height of one hundred feet or more; one, the *Giantess*, spouts a column of water two hundred and fifty feet high, while the steam is forced nearly a thousand feet higher. The eruptions occur at periods varying from thirty minutes to about as many hours. Each is preceded by a gentle overflow of water, and commonly lasts from a few seconds to fifteen minutes, but in a few instances continues for more than two hours. The intervals between eruptions rarely vary more than a few minutes, but careful observations show that their length is increasing, and the energy of eruption is diminishing.

The deposition of silica from the cooling waters takes fantastic forms. In many instances the rock thus produced is richly colored with variegated bands. The "Pink-and-White Terraces" of New Zealand derive their name from this fact.

Mud Volcanoes.—Mud "Volcanoes" are hot springs that have piled cone-shaped mounds of mud about their vents. The mud hardens into a compact mass. Steam and sulphurous gases are commonly the products of these alleged volcanoes. The energy displayed is feeble, and

the mud cones are seldom more than twenty or thirty feet high. The mud consists of fine clay formed from the mineral matter of the spring. Mud volcanoes are common in all volcanic regions.

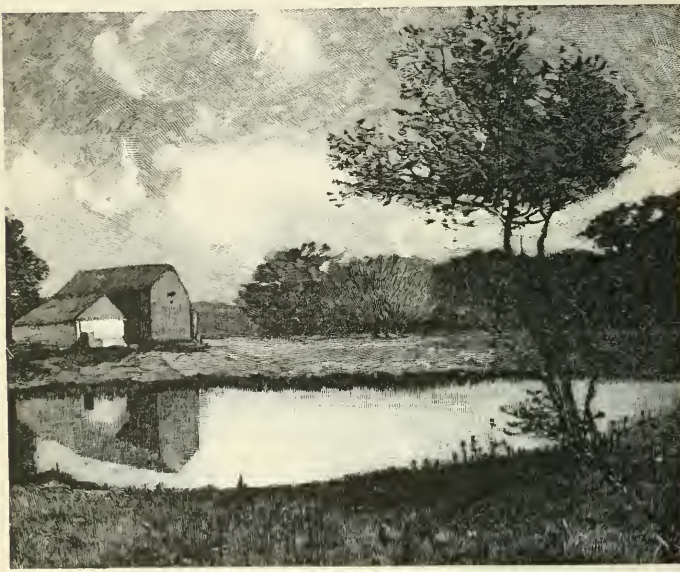
Underground Streams.—In addition to the multitude of surface streams, a large part of the water finds its way to the sea—not simply by percolation but in underground streams. Undoubtedly the run-off of most streams is mainly above ground, but at the same time, a considerable part of their waters flows below the surface.

There are several reasons for this. In the first place, whenever a stream flows in a gravelly channel, a great deal of the water must necessarily sink into the gravel and flow along the old bed-rock bottom. The same is equally true in the case of rivers that flow through light, sandy rock waste, such, for instance, as those of the Basin Region, west of the Rocky Mountains. The underground flow of such rivers is strong even when fierce summer heat has evaporated their surface waters.[8]

In many cases, too, small river channels have been obliterated for one purpose or another. Now, although the surface flow may be destroyed the underground current is not; on the contrary, it is apt to be strengthened. Thus, in some of the larger cities many small drainage courses have been covered up in grading the streets, and in several instances it has been found necessary to excavate these old water-courses and sewer them.

In New York and London the channels of many such streams have been plotted, and drainage maps showing their former courses are used by the Boards of Health in sanitary investigation. In several instances these streams, becoming obstructed, have forced their way to the surface and flooded the streets with a deluge of water. Such experiences are not uncommon; they occur in almost every large city.[9]

Of still greater interest, though not more important, are the various "Lost" rivers. These streams receive their name from the fact that for part of their courses they are ordinary surface streams; for the rest, they flow through subterranean channels. In some instances the water of



A SINKHOLE, EDMUNSON COUNTY, KENTUCKY

The throat leading to the cavern below has been artificially closed.

the river disappears by percolation; in most instances the stream pitches headlong into a "sinkhole."

In the limestone area of southern Indiana, Kentucky, and Tennessee, underground rivers are very common.[10] One of these rivers winds its way beneath the floor of Mammoth Cave. Its waters contain a species of fish and two or three of insect life that have rudimentary eyes

only—and indeed they have no use for perfect organs, for never a ray of light penetrates to their abode.

Similar streams are found in Weir's Cave, in Luray Cave, and, in fact, in almost every limestone cavern. In Derbyshire, England, the Hampo and the Manifold flow many miles each through an underground passage. In both instances the identity of the stream is proved by throwing a floating body into the water above the beginning of its underground course and capturing it when it reappears.

In Southern California, where water is required for irrigation, underground streams have been captured and forced to the surface. This is accomplished by building a dam across the stream at a point where it emerges from the cañon to the open plain. The dam extends from the surface of the ground down to bed-rock. The water is thereby forced to the surface.

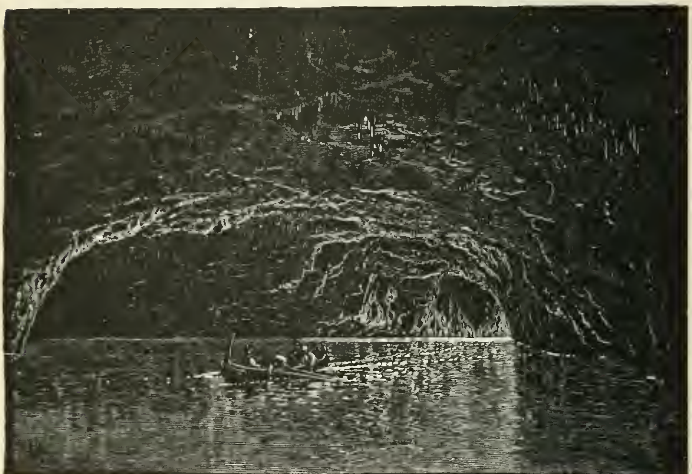
It is noticeable that where such submerged dams are constructed, the artesian wells in the plain below are seriously impaired—the flow of water being greatly reduced—all of which seems to show that underground waters have a much greater circulation than is generally imagined.

Physiography of Underground Waters. — Although the work of underground waters is by no means so extensive as those flowing above the surface, they are nevertheless of great importance especially from an economic point of view. Under almost any conditions water has a considerable solvent power, and hot water, especially if under pressure, will dissolve many kinds of rock that are not affected by cold water; when the solution cools, however, much of this matter is again freed from solution. In the meantime, if the water has been forced to the surface, the substances dissolved will be carried along and there deposited.

Sometimes the deposits are spread hap-hazard over the surface of the ground, forming *sinter* or *tufa*. If the latter

happens to cover loose rock waste or soil, a cavern or cave will result if the material under it be removed.

In other instances the hot waters, charged with mineral or metallic salts, flow into deep fissures in the rocks. As the water cools the soluble matter is deposited on the walls of the fissure until, finally, the latter is filled, thereby forming a *mineral vein* or *lode*. All through the various



BLUE GROTTO, ISLAND OF CAPRI, ITALY

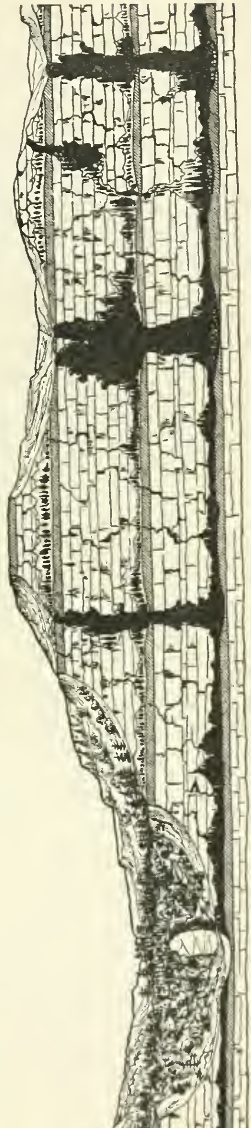
mountain regions of the earth, gold, silver, copper, lead, and other valuable metals have been deposited in such fissures and veins.[11] Thus underground waters are a vehicle by which many useful metals are carried from the interior to the surface of the earth.

Caverns.—Caverns and caves, although sometimes formed at the surface in the manner already noted, for the greater part are formed underground by the action of water.[12] The water merely dissolves the rock and carries

it off, leaving a cavern. Clay, slate, granite, and sandstones are not readily dissolved; and in regions underlaid by such rocks, caverns are rare. Limestones, on the contrary, are quite soluble, and in localities where they are the prevailing rock, caves and caverns are common. In the cavern district of Kentucky, Tennessee, and Virginia[13] small pieces of sharp flint are plentifully distributed throughout the limestone. These are tossed about and carried along with the water and thus become powerful cutting tools.

Between the solvent power of the water and the incessant cutting done by the flint particles, the underground channel is worn deeper and wider till a cavern, perhaps a score of miles long and many feet deep, is formed. Very likely it has hundreds of galleries and branches; time alone is necessary to give it vast dimensions.

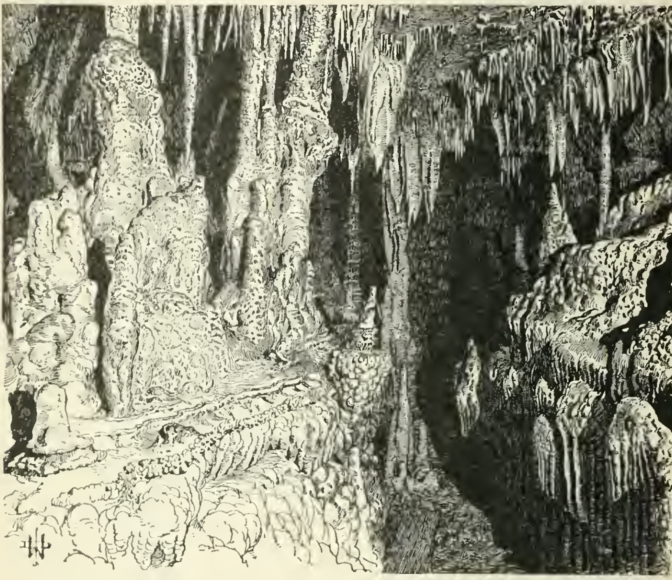
But time alone will see the factors that made the cavern destroy it. In the first place the surface waters are constantly at work wearing away the rock that forms the roof or dome of the cavern. By and by breaks are made



THE CHANNEL OF AN UNDERGROUND RIVER—SHOWING THE FORMATION OF SINKHOLES AND CAVERNS

through the roof and sinkholes are thus formed. These increase in size and in number until the dome is destroyed. The river is then no longer an underground stream; it is a surface river flowing in a limestone cañon. Natural Bridge, in Virginia, is a remnant of one of these domes; the rest of the roof has been carried away.[14]

In the second place, parts of these caverns are filled up by



A PASSAGE IN LURAY CAVERN—STALACTITES AND STALAGMITES

the limestone itself. In places the water charged with limestone leaks or filters through at the top of the dome, falling drop by drop. A part of the water leaves a minute portion of limestone at the roof; the rest falls to the floor of the cavern, where a little more of the water evaporates. So, little by little, the deposited limestone gathers into icicle-shaped columns, both at the roof and the floor of the

cavern. The former are called *stalactites*, the latter *stalagmites.* In time the two join, forming a single column, and as the water trickles down their sides they increase in size, and thus the cavern is filled.

Perhaps, in the course of time, this same mass of limestone may be dissolved away and redeposited elsewhere. At all events, the process illustrates the general law that governs cavern-formation in these regions. *Water in motion dissolves limestone and makes caverns; still water deposits limestone and fills them up.*[15]

QUESTIONS AND EXERCISES.—If possible find the depth of each of half a dozen or more wells in the neighborhood in which you live: compare the distance of the surface of the ground to the surface of the water in the wells.

To what depth must a well be sunk before it will fill with water?

Will one be apt to find percolating waters in regions having but a very little rain?

Explain why water in very shallow wells is apt to be impure

How do springs become "mineral" in character?

Why does rain water contain no mineral matter in solution?

Why are geysers and hot springs confined usually to volcanic regions?

Under what circumstances or conditions can water be heated above the ordinary boiling point? *(See almost any text-book in physics.)*

From the diagram, p. 129, decide the conditions which will cause underground streams or percolating waters to form a swamp.

Describe a way in which caverns may be formed at the foot of sea cliffs that face heavy waves.

How are the sinkholes in the limestone regions formed?

By using lime-water such as is obtainable at the druggist's, suggest a way in which stalactites may be artificially formed.

COLLATERAL READING.

SHALER.—First Book in Geology, pp. 66–87.

SHALER.—Aspects of the Earth, pp. 96–142.

POWELL.—Irrigation and Artesian Wells, pp. 203–290. *United States Geological Survey, 11th Annual Report*, Part 2.

LE CONTE.—Elements of Geology, pp. 103–113.

UNITED STATES GEOLOGICAL SURVEY.—Map of Yellowstone National Park.

NOTES

[1] If the rocks are near the surface and the amount of water is considerable, swamps may result. That is, swamps may be an incident of imperfect underground drainage, as they are of imperfect surface drainage.

[2] The fissures between the ends of faulted strata are very frequently the channels of springs, and sooner or later the fissure is likely to be closed up by deposits from the spring water.

[3] This may be seen in the cases of streams that flow through a region of pervious soil. Such streams steadily increase in volume, although for many miles they receive no tributaries. As an example, Spanish Fork, on the west slope of the Wasatch Mountains, receives only two or three small tributaries from the summit to the base of the mountains. It begins as a rivulet, scarcely larger than one's arm; it reaches the base of the range, a mountain torrent twenty feet across. Almost the whole increment is due to percolation.

[4] The sand valleys are apparently *hills*, but, in most cases they are valleys filled with rock waste carried thither by winds. In the saturation of these accumulations of rock waste capillary attraction is an important factor; for this little-understood force is not only an agent of accumulation, but one of retention also.

[5] The amount of desert land made productive solely by artesian wells has been greatly exaggerated by senseless guesses. Such estimates commonly make the aggregate as "millions of square miles." As a matter of fact all the artesian wells in the world do not supply an area equal to that of the State of Delaware with the water necessary to produce the whole of its crops.

[6] The difference between springs and percolating waters is mainly one of degree; issuing from a channel it is a spring, but if the water merely oozes through the soil it is considered only as an example of percolation. In Florida there are a number of springs, so-called, that discharge each an amount of water sufficient to fill a river bed. Orange and Silver Springs are so large that small river craft easily enter the mouths. These springs, as a matter of fact, are the exits of underground rivers.

[7] From time immemorial geographers have explained the peri-

odical spring on the supposed existence of a siphon-shaped channel. Doubtless such channels exist, but not a single one has ever been discovered. In a few instances the pressure of accumulating gases is known to be a cause of intermittent flow, but in the great majority of cases the cause of periodicity is unknown. One of the most remarkable periodical springs occurs in Palestine near the old convent of Mar Jirius. This spring is quiescent for about two and a half days, and its period of activity lasts for several hours. It is probable that the stream flowing from this spring is the Sabbatic River described by Josephus, which rested for six days and flowed on the seventh. The fact that such springs gradually decrease their periods of quiescence, and finally become regular, bears out this supposition. A spring near Rogersville, Tennessee, is celebrated for the enormous quantity of water ejected. Its period of flow occurs about every half hour, lasting only a few minutes. The Bullerborn, once a famous intermittent spring of Westphalia, has now a constant flow. In regions of very high tides, periodical springs are sometimes formed by tidal action. The fresh water is pushed back by the tide, until it emerges to the surface through self-made channels.

[8] In desert regions, where the heat is intense, there are many instances of rivers that are dry "washes" in the daytime, and fair-sized streams at night. Water nearly always can be found at a slight depth, by digging for it. In the daytime, the enormous evaporation causes the water to disappear. In the night, or during cloudy days, the evaporation is lessened and the percolating waters rise to the surface. This phenomenon is occasionally noticed in the lower courses of Humboldt, Carson, and Reese Rivers, in Nevada. The underground part of the river is nearly always to be found.

[9] Considerable trouble from this cause occurred near the junction of Oxford Street and Edgeware Road, London, and the reason was the fact that the famous Tyburn flowed in this locality, crossing Oxford Street a little to the eastward of the entrance to Hyde Park. About four hundred square feet of Broadway, New York, recently caved in from a similar cause. The foundations of a costly church in Philadelphia sank in the quicksand before they were completed, and the large sewer under one of the principal streets has caved in several times—all because they were undermined by buried streams.

[10] At Orangeville, Indiana, an underground stream comes to the surface and flows with sufficient force to turn a mill-wheel. Only a few miles away, Lost River, a considerable stream, sinks out of sight. San Pedro Springs, near San Antonio, Texas, is the outlet of an underground stream. Giant Spring, near Great Falls, Montana, is the outlet of Little Belt River, which disappears and flows underground for thirty miles of its course. In Alabama, the engineers of the Anniston and Atlantic Railway discovered an underground stream sixty feet below the bed of Coosa River. According to Greek legends, the Alpheus, the river of Peloponnesus, which Hercules turned through the Augean stables, sank underground and emerged to the surface somewhere in Sicily. As a matter of fact a considerable part of the course of the Alpheus is underground, and there is a spring in Sicily discharging a large volume of water. It is hardly necessary to add that the two have no connection.

[11] As a rule such veins have a very symmetrical banded appearance, the stripes on the right hand corresponding with those on the left. In California, these veins are called "ribbon" rock.

[12] There are several instances in which caves have been formed in volcanic rocks. Fingal's Cave, on the Island of Staffa, west of Scotland, is an example. It is more than two hundred feet in length, and is surmounted by a dome sixty feet high. In many instances waves have hollowed out caverns in rock cliffs.

[13] Mammoth Cave, Kentucky, is a labyrinth of passages aggregating more than two hundred miles; the length of the cave on a straight line is about ten miles. Some of the vaults and domes are two hundred and fifty feet high. There are several other caves in the vicinity nearly if not quite as large. Weir's Cave and Luray Cavern, both in Virginia, are smaller than Mammoth Cave. Being limestone caverns they do not differ from the latter. Howe's Cave, Schoharie County, New York, is one of the few large caverns of interest in the northern Appalachian region. In the grotto of Lueg, Illyria, there are three galleries, one over another. The cavern of Adelsberg, Austria, is the abandoned channel of the Poik. Its length is not far from two miles; its labyrinthine passages aggregate many miles. A considerable part of the course of the Poik is underground. Probably the underground passage and caverns of the Timavo have been more thoroughly investigated than those of any other stream. The

river flows to the Adriatic, a few miles north of Trieste, and its character has been known for more than two thousand years. Concerning it Virgil wrote :

> . . . et fontem superare Timavi
> unde per ora novem vasto cum murmure montis
> it mare proruptum, et pelago premit arva sonanti.
>
> —*Æneid* I., 247.

Virgil's description is no longer true of the delta, for the *nine* mouths have become only three in number.

[14] Many similar natural bridges are known to exist in various parts of the world. Near Bogota, Colombia, a natural arch spans a chasm nearly four hundred feet deep. The arch is a double one, the lower one being composed of three large fragments that, detached from the upper arch, fell in such a manner as to wedge themselves between the perpendicular walls. In one of the deep cañons of Arizona a huge mass of rock has fallen and become wedged between the walls of the chasm, thereby forming a sort of natural bridge. A natural bridge spans Pine Creek, in Gila County, Arizona. Like that in Virginia, it is the fragment of the dome of a stream that once flowed underground. The arch is about four hundred feet wide and the span is about a thousand feet in length. The underside of the arch is water-worn, but since it was formed the creek has cut its channel more than two hundred feet downward. In several instances the arch more properly constitutes a tunnel. One, near Clinch River, Virginia, is more than half a mile long, and is a part of the route selected for a railway. In almost every instance a stream of water flows under the arch, and its current carries away the fragments that fall from the roof.

[15] The distribution and also the concentration of certain economic minerals, in many instances, has resulted from the flow of underground waters. Gold has been dissolved from certain rocks and gradually concentrated in veins through their action. Iron salts have been leached from rocks and deposited in other rocks by the same agency. Beds of sand through which water containing lime percolates, in time, become sandstone, the grains of sand being cemented together by the lime carried in the water.

CHAPTER IX

THE WASTING OF THE LAND: THE WORK OF AVALANCHES AND GLACIERS

A GREAT deal of the moisture mingled with the air falls upon the land in the form of snow. Excepting very cold regions, the snow that falls at altitudes below three or four thousand feet melts with the coming of spring and flows away in the various stream channels. In high mountain regions more or less snow falls at altitudes in which the temperature is rarely higher than the melting point of the snow. In such localities, therefore, but little of the snow can melt where it falls.[1]

In the Alps and in the higher ranges of the western United States, the heaviest snows fall between the altitudes of six thousand and nine thousand feet. Very little accumulates below four thousand feet, and but little falls above twelve thousand feet; in fact but little moisture exists at such high altitudes.

At high elevations, even though the fall might be slight, it would seem as though the accumulation would increase until the mass of snow exceeded that of the mountains. In certain polar lands it is possible that this may be occurring, but in high mountain regions various agencies operate to prevent such enormous accumulation. Among them are evaporation, wind, avalanches, and glaciers. They not only remove the snow and ice, but they are also powerful factors in wearing away the land and in transporting rock waste.

Evaporation is a very active agent in the removal of snow. Ice and snow evaporate just as does water; and at great heights, where the air does not press so heavily as at sea-level, evaporation is very rapid. This is seen when frozen roads become dry and dusty without thawing.[2]

Winds are also a very potent factor. In high mountain regions the wind has a force that is almost unknown in lowlands, and the gales that rage among snow-covered peaks quickly clear the dry snow-dust from every exposed surface and drift it into ravines and cañons.[3]

There are two factors at work, however, that are interesting, not only because they remove an enormous amount of snow, but also because in transporting it they become physiographic agents of very great importance. These are avalanches and glaciers.

AVALANCHE BASIN, MONTANA

The slopes are too steep to permit the accumulation of snow, and the latter, gathering within the basin, has formed the lake at the bottom of the cliff.

Avalanches. — When a great body of snow, resting on a steep slope, suddenly slips and plunges down the incline, the moving mass is called an *avalanche*, or *challanche*. Excepting the matter of the material transported, which is mainly snow, the avalanche does not differ materially from an ordinary landslide. But while it is very rare that a second landslide takes place in the same track, it is evident that an avalanche may occur every time the snow falls on the slope. The snow

accumulates on the steep slope until its great weight causes it to slip, and the great mass gathering speed, moves downward with a terrific roar.

In the Alps, where as a rule, the slopes are steep,[4] such downfalls take place frequently and regularly. In many places the avalanche tracks are as definitely marked as the river channels. Indeed, one may consider the avalanche track as the torrential part of a stream whose flow is occasional and spasmodic. Like the mountain torrent, too, it carries to lower levels an enormous amount of rock waste stripped from the slopes. Not only are avalanche courses distinctly marked, but expert mountaineers who have acquired experience in discerning weather signs are able to predict the occurrence of the snowslide with great certainty. The avalanche, therefore, is a feature of mountain economy not less normal than the mountain torrent.

The most destructive avalanches occur in the first hours of sunshine, just after a snow-storm.[5] The flakes are then so fine and smooth that they have but little coherence, and almost any disturbance may start them. The footstep of the chamois or a gust of wind imparts motion to a handful of snow, and it begins its descent. Gathering fresh material as it advances, and increasing in velocity every moment, it soon becomes a force that sweeps everything before it, carrying havoc and destruction perhaps into the region of cultivated fields and human habitations, far beyond the foot of the slope. Rocks crash right and left and the whirl of the wind carries eddies of snow a thousand feet or more into the air.

When avalanches follow their customary tracks they are neither especially dangerous nor destructive, unless the snow and rock waste reach beyond their ordinary limits. But in many instances they have taken place in localities previously free from them, and these are the cases in which

the destruction is greatest. Not only is everything destroyed along the path of the moving snow, but the effects are even more apparent along the edges; for the blasts of wind set in motion by the swiftly moving snow, fell every vestige of timber a thousand feet or more on both sides. In recent years, places that the experienced mountaineers have discovered to be possible avalanche tracks, have been artificially guarded, so as to prevent the formation of dangerous snowslides.

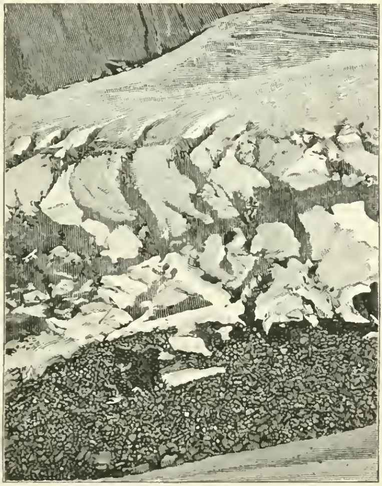
Another form of avalanche occurs in the Alps late in the season, at the beginning of warm weather. Instead of light, powdery snow, its volume consists of ice and coarse snow mixed with rock waste.[6] The lower part of the snow and ice are undermined by water as the ground on which it rests thaws. Finally the whole mass slides down the incline. These avalanches do not differ in any material respect from landslides.

Glaciers.—A great part of the snow that falls on high and steep slopes is either blown into ravines by the wind or is tumbled into them by avalanches. In the upper part of the ravine the snow is light and flaky, but farther down it has begun to melt, and instead of crystals it consists of little granules of ice, called *névé*. Still farther down the ravine, the névé has a striped or banded appearance.[7] Then the surface takes the form of irregular wave-shaped ridges, and finally the surface is a field of ridges and hummocks,[8] half-drowned in streams of muddy water, and ending in a mountain torrent.

All this mass of ice and snow constitutes a *glacier*. It is in motion, and excepting the velocity, which is so slow as to be almost imperceptible, its movements are much like those of a stream of water. The flow is faster at the surface than at the bottom, and it is also swifter in mid-stream than at the edges.

A "STREAM" GLACIER

Because the glacier moves more rapidly in the centre than at the sides of the stream, the surface is scored with cracks and chasms called *crevasses*. These are roughly parallel and cross the glacier in lines which, in many instances, point upstream.[9] In some cases the crevasses form gently curving parallel lines that are not unlike the ripples in a river. Ordinarily, the crevasse is narrow and only a few feet deep; but in some places it becomes a chasm fifty or sixty feet from top to bottom. Crevasses are most numerous in that part of the glacier where the slope is the steepest; and, in general, they mark what in a river would be the rapids. The velocity of the current varies. On a gentle slope it may not be more than three or four inches a day; on a steep incline it may be half as many feet. In summer, when the temperature is above the freezing point, the motion is much swifter than in winter—in some instances twice as great.


CREVASSES AND MORAINE, NISQUALLY GLACIER, WASHINGTON

As the ice-stream makes its way down the ravine, fragments of rock fall from the confining banks and lodge at the edges. In time, these accumulate until they form walls of considerable regularity. These walls constitute the *lateral moraines* of the glacier. If two or more glaciers flow into the same ravine, the moraines on the sides that join unite to form a *medial moraine*. In some instances

several medial moraines may be seen stretching with great regularity for a long distance.

Toward the lower end of the glacier, much of this sort of rock waste gets to the bottom, in front of the ice-stream. In summer, when the lower end of the glacier melts to a considerable distance up-stream, the rock waste, consisting mainly of large bowlders, is strewn along the bed. But in winter, when the ice-front again advances, the scattered bowlders are pushed forward, forming across the path of the glacier the long windrow of rock waste that constitutes the *terminal moraine.*

The moraines of a glacier are one of its most interesting and important features. Not infrequently the shape of the ravine is such that the rocks composing the lateral moraine are pushed against the sides, forming walls as regular as though they had been laid by human hands. Moreover, while the lateral moraines may decrease in size, the terminal moraine is constantly growing in volume.

Glacial Ice Sheets.—Glacial movements are not confined to the ice streams of ravines, however. The sheet of snow that projects over the edge of a roof is a perfect illustration of glacier motion; and so, too, is the patch of snow on a steep hillside that gradually creeps downward or acquires a distorted shape.

But there are remarkable fields of ice many miles in extent, that exhibit all the phenomena of glacier movement. These vast fields are found mainly in polar regions. They are not confined between the sides of ravines; they are ice sheets of vast extent. Probably the greater part of the sheet is gradually settling downward; certainly the ice in many places is projecting beyond the edges and breaking off.

The Greenland ice sheet is a striking example. To the best of our knowledge, almost the entire island is covered

with ice and snow that have been accumulating during long periods of time. So far as known the only rock that reaches above the surface of the ice is found near the coast, where the ice-covering is thinnest.

Along the southern coast much of the ice and snow disappears by melting. Farther north, however, the ice reaches the coast—sometimes descending into the fjords, sometimes presenting an unbroken wall from five to fifty miles in extent. In places the flow of the ice is compara-

BIRTH OF THE ICEBERG

The buoyant force of the water is shearing the fragments, and the latter float away.

tively rapid—as much as forty or fifty feet a day. The fragments broken from the ice front are icebergs. Sometimes they tumble from the top; in other instances the edge of the sheet is pushed out so far that the buoyant force of the water breaks a fragment from the sheet, and it floats off.

Humboldt Glacier, on the west coast of Greenland, is a striking example of the ice-sheet. For a distance of about sixty miles, its ragged front, broken here and there by rock-cliffs, forms a sea-wall in places several hundred feet

high. By far the most stupendous examples, however, are those of antarctic regions. Apparently the ice-sheet is continental in size and, judging from the thickness of the icebergs, it is probably several miles thick.

Occurrence of Glaciers.—In general, glaciers begin above the line of perpetual snow and extend usually a short distance below it. In high latitudes, where the weather is cold, they occur at no great altitude above sea-level, but the nearer they are to tropical regions, the higher the altitude. In low latitudes they rarely occur below the altitude of fifteen thousand feet, while in polar regions they usually flow into the sea.

The largest stream or ravine glaciers known are in the Himalaya Mountains; the best known are those of the Alps. Along the northern coast of Norway there are fine examples; in the Patagonian Andes, and along the Alaskan coast, almost every arm of the sea contains one or more of them. Study the character of these coasts on a good map. In the Rocky Mountains there are numerous glaciers, but none of them is of great size. Several of the glaciers of Mounts Shasta and Tacoma (Rainier) rival the Alpine ice-streams in extent. Muir Glacier, Alaska, has a frontage of two miles on the sea.

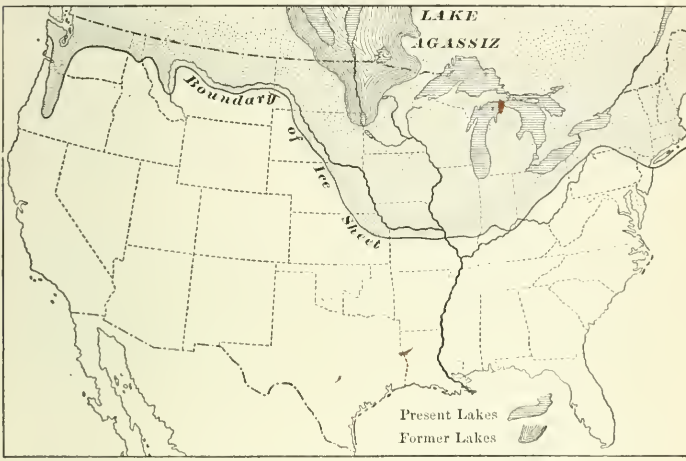
Most of the rivers flowing from the high slopes of mountains that reach above the snow-line have their sources in glaciers. Find examples in the Alps.

Physiographic Effects of Glaciers.—The results of glacial action are readily observed in the glaciers of the present time and, indeed, they are so full of character that they are a most excellent key whereby the stupendous effects of the glaciers of prior geological times have been studied.

The chief effects of glacial action are erosion and transportation. Ice alone is so soft that it has little or no

wearing effect on hard rock, but if a moving mass of ice drags or pushes fragments of rock along at the sides and bottom it becomes a cutting tool of great power. It planes, gouges, or scratches, according to the character of the rock over which it moves.

All through the northern United States and Canada, nearly to the Rocky Mountains, the surface has been scoured by glacial ice, and many thousand lake basins



REGION OF GLACIATION IN THE UNITED STATES

The heavy line shows the limit of terminal moraines: erratic bowlders occur in occasional localities a little farther south of the line.

have been made or shaped. In the exposed rock of New England and New York, the grooved and rounded surfaces are one of the most marked features, and everywhere the erosion is so characteristic as to reveal its origin. The northern Appalachian Mountains were worn and broken, and the wide gap between the Adirondack and Catskill ranges—both groups being parts of the Appalachian folds—was probably made at this time. What has been the

effect of this gap on the commercial development of New York? That the surface of the ice-sheet did not reach quite to the top of the highest peaks of the Adirondack and White Mountains is inferred from the fact that certain alpine species are still found at their summits that do not occur at a lower level.

The same markings are equally plain throughout northern Europe, and the coasts of Norway and the British Isles probably received their present frayed and ragged appearance at the same time that so much of North Amercia was covered with glacial ice.

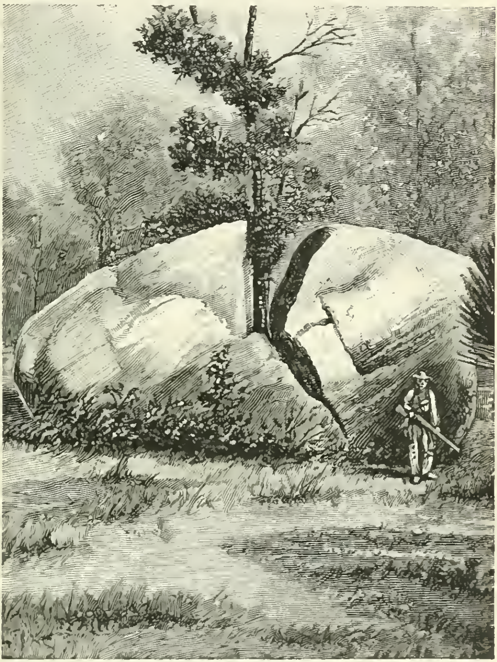
A DRUMLIN

In many instances the surface is covered with fertile soil.

The transportation of material is a still more noticeable effect of glaciation, and the rock waste that has been removed, is commonly known as *drift.* Glacial drift is unsorted material, and in size the pieces vary from grains of sand to bowlders weighing several thousand tons. In character, the gravel of drift differs materially from stream gravel; for while the latter is composed of uniformly rounded pieces the fragments of the former are rough and angular, with one or more faces planed smooth.

Glacial rock waste or detritus has been deposited in various forms. Much of it has been spread over the sur-

face as an imperfectly mixed mass of clay, sand, and gravel. These deposits are the well-known *till* plains of northern Europe and the United States. Not infrequently the material occurs in rounded hillocks or *drumlins*, or perhaps in long ridge-shaped bars, called *eskers*. The former are very common in the New England Plateau, the northern lake region, and also in England and Scotland. Several of the islands in Boston harbor are drumlins.



SPLIT ROCK: AN ERRATIC BOWLDER

The butternut-tree, growing from the cliff, is forty years old.

Near the southern limit of the glacial ice-sheet the drift occasionally takes the form of long ridges—perhaps many miles in extent, and one hundred feet or more in height. In nearly every instance these heaps are moraines. A part of Long Island is probably a terminal moraine, and several of the ridges that cross New Jersey are of similar origin. Many of the low ridges extending into the valleys of Colorado are moraines.

A remarkable form of drift is found in the rounded blocks of stone strewn over the surface of the New England and Middle Atlantic States and a few other localities. These are commonly known as *erratic bowlders.* With respect to mineral character the bowlders are of many kinds; those of the northeastern United States are mainly of granite. The most interesting feature about them is the fact that they are unlike the rock in the locality where they are found; in some instances they certainly have been brought from a long distance. Some of them are of enormous size; one, Split Rock,[10] near Mount Vernon, New York, weighs not far from five hundred tons.

Icebergs.—The formation of icebergs along the sea-front of glaciers becomes an important factor in several ways. The icebergs from the west coast of Greenland float southward during late spring, and during May and June cross the routes of trans-atlantic steamships, thus becoming a menace to navigation. Sometimes several hundred of them are drifting about in the vicinity of the Newfoundland Banks, and remain there until they melt or are broken up by storms. The huge blocks broken from the Antarctic ice-sheet drift about over a very large area, sometimes being found as far north as latitude 40° S. In the North Pacific Ocean the icebergs are small and are rarely found beyond the partly enclosed waters of the Alaskan coast and Bering Sea.

QUESTIONS AND EXERCISES.—Describe any effects you have noticed with relation to snowslides on the roofs of buildings or steep slopes.

A mass of snow weighing ten thousand tons moves with a velocity of twenty-five feet per second; what is its momentum in foot-pounds? Would this force be sufficient to break off or uproot large trees?

In a previous paragraph it is stated that the water issuing from the end of a glacier is muddy; account for the presence of the mud.

Explain the way in which rock fragments may get to the bottom of a glacier. Why are the scratches made by these fragments parallel?

Why are there no glaciers in the Appalachian Mountains?

The map on p. 157 shows the terminal moraine of the great ice-sheet; describe its course and location. Name two large lakes situated in the basin of former Lake Agassiz.

Describe any evidence of glaciation in the neighborhood in which you live, noting drumlins, eskers, moraines, markings and scratches, erratic bowlders, or drift. If possible delineate them on a map.

COLLATERAL READING AND REFERENCE.

TYNDALL.—Forms of Water.

TYNDALL.—Hours of Exercise in the Alps.

LE CONTE.—Elements of Geology, pp. 569–583.

NOTES

[1] It is rare that snow accumulates to a depth of more than ten or twelve feet on a level area. On mountain slopes the snow is not evenly distributed, most of it finally lodging in ravines and places not exposed to the sweep of the wind. In laying the foundations for the observatory at the summit of Mont Blanc, the snow and ice were so deep that no rock bottom could be found at a depth of sixty feet. On the western slope of the Sierra Nevada Mountains the fall of snow sometimes reaches twenty feet on the level, while the drift may be several times as great.

[2] Wet clothing hung out to dry in very cold weather first freezes and then gradually dries. An inspection of Table III., Appendix, shows that at a temperature of $-40°$ F. a small amount of moisture may still exist in the atmosphere.

[3] The power of wind in drifting loose soil has already been noted. But snow is less than one-quarter as heavy as soil of average material; hence the work of wind is far more effective.

[4] In certain parts of the Rocky, Cascade, and Sierra Nevada Mountains avalanches are of frequent occurrence, but they are by no means so common as in the Alps. In the latter ranges the slopes are steeper and the snowfall is considerably greater. It is not improbable that such snow-slides are just as common and quite as destructive in the Caucasus and the Himalaya Mountains as they are in the Alps.

[5] These are the *poudreuses* (powdery snow), and they are the most dreaded of all snowslides. Damp snow does not shear and move readily; it is the gathering of light, dry snow, little by little, until finally the whole mass is in motion, that is the distinctive feature of this form of avalanche.

[6] This form is known as the *avalanche de fond.* It is rarely destructive.

[7] The bands are alternate layers of ice and dirty snow. The ice is formed of snow that has been subjected to great pressure. Because of the pressure all the air has been squeezed out, and for this reason the ice is tolerably clear and blue. The bands of snow contain air and are therefore whitish and opaque.

[8] The ice hummocks are conical in shape and, if present, are found almost always at the lower end. Not infrequently one of these hummocks is surmounted by a bowlder of several tons weight. The bowlder protects its support from the heat of the sun, while the latter melts the ice around the lower end of the column. Sooner or later the ice column breaks and the bowlder falls to a lower level, where the same process is again repeated.

[9] This peculiar feature at one time gave rise to the opinion that there might be an up-stream motion to a glacier. The reason for their direction, however, is evident; the crack or break is necessarily at right angles to the direction of the strain. Now the movement of the ice is twofold—down stream and away from the bank. Therefore when the ice breaks the crack points diagonally up the stream.

[10] Many years since this bowlder broke into two parts along a cleavage plane. A butternut-tree sprang up in the cleft and in time its trunk has wedged the two fragments apart in the form of a V-shaped opening. In the northern part of Westchester County a large erratic block has been deposited on the top of three smaller stones, the latter forming a very firm tripod. In a number of instances one bowlder has been deposited on the top of a boss of rock in such a position that the equilibrium, while more or less unstable, cannot be readily overthrown. Examples are found throughout the New England States, and they are popularly known as *rocking stones.* There is a fine example in Bronx Park, New York City. Rocking stones are also common in the glaciated regions of northern Europe.

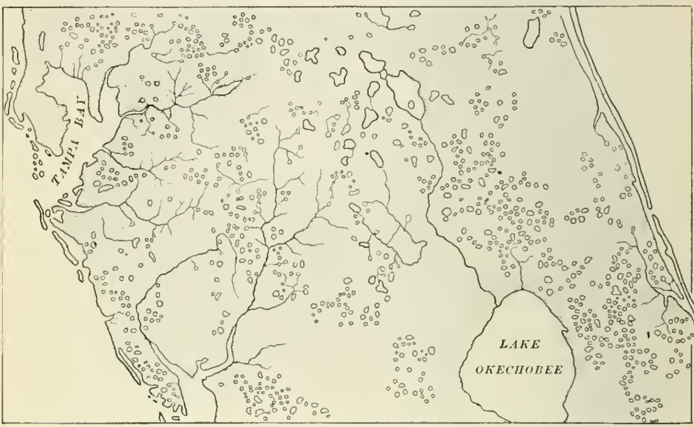
CHAPTER X

THE WASTING OF THE LAND: THE RESULTS OF IMPERFECT AND OBSTRUCTED DRAINAGE. LAKES AND MARSHES

In flowing from higher to lower levels along lines of least resistance, the water may find its passage temporarily obstructed, or perhaps wholly blocked by obstacles. Sometimes a ridge of land prevents its progress; in other cases a landslide or, perhaps, a stream of lava athwart the channel prevents its progress. The water therefore spreads out, forming a *lake*,[1] *pond*, or *marsh*. In places where the flow is obstructed, one of two things must occur—either the water will collect until its surface is high enough to flow over the lowest part of the rim, or else it will spread over the surface until the amount that evaporates just equals that which flows in. The area whose waters flow into the lake constitutes its *basin*. A large basin usually has several rivers and many small streams that are its tributaries or feeders.

Marsh Lakes.—In a region of considerable rain-fall, if the general slope be very decided, perhaps there may be no lakes and ponds, for the reason that the water flows off, meeting no obstructions which cause it to collect in basins.[2] On the contrary, if the surface be flat, the water, finding no definite channels, spreads over the surface and forms a multitude of small ponds. In Florida and along the Gulf Coast there are excellent examples, and they are commonly called *marsh lakes*.[3]

A marsh lake of large size or considerable depth could not form in perfectly flat lands, for the reason that, after reaching a certain height, the water would flow off as fast as it was supplied. For a similar reason, such lakes could not be very numerous on a surface that had a considerable slope.[1] But while many—perhaps most—of the lakes have been formed by the surplus of rainfall over drainage, there are many thousand lakes that are the result of factors with which rain-fall has no direct con-



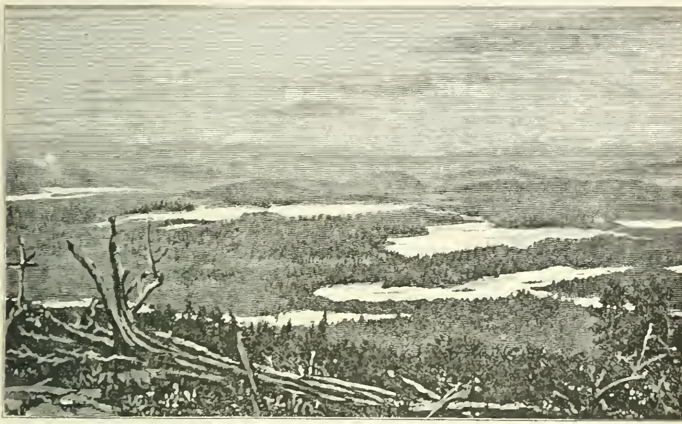
MARSH LAKES, FLORIDA.

nection. The most important are those whose basins have been shaped largely by the action of moving streams of ice—that is, by glaciers.

Glacial Lakes.—A glance at a good map of the northern part of North America shows that the lakes of this region are its most remarkable surface feature. As a rule they are long and narrow, and if a group of them be considered, it is at once apparent that their axes, or lines of greatest length, are nearly parallel. Careful investigations

have shown that not only are such lakes comparatively much deeper than the marsh lakes previously described, but that also, in most instances, their basins have been wrought in the hardest rocks. In many instances, too, their rims are walls of bowlders that could scarcely have been more regular, had the courses of rock been laid by human hands.[5]

Very frequently such lakes occur in chains, a river following the course of each chain; indeed, these lakes are



GLACIAL LAKES

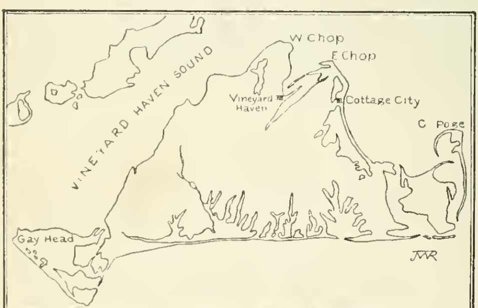
A group in the Adirondack Mountains, New York.

merely incidents in the history of the river. In a few instances a cluster of such lakes apparently radiates from a central point, as is seen in the "finger" lakes of New York. Lakes of this type are closely associated with the great accumulation of glacial ice[6] that formerly covered a large part of the northern hemisphere. The lakes themselves are found in glaciated regions only—never elsewhere. They are therefore called *glacial lakes* or, in the British Isles, *tarns*.

Accidental Lakes.—There are other lakes whose origin is the result of accident; such as the destruction of a river loop, the damming of a stream,[7] the formation of a bar across an estuary or cove, or the sinking of an area of land. Very many lakes have come suddenly into existence through one or another of the causes named.

In the illustrations pp. 108 and 110 there is shown a type of lake that is common along the bottom lands of the Mississippi and other rivers that flow through level plains. The origin of such lakes is very apparent. The lakes themselves are manifestly the abandoned loops of rivers, and they are formed when the river straightens its channel. The *moat* thus formed remains filled with water. Perhaps a bayou or small stream may be left as a feeder, but more likely the moat becomes a stagnant pool, sooner or later to disappear—possibly overgrown by vegetation, possibly buried under the sediment brought down by floods.

Another type of accidental lake occurs along low, flat coasts. These are the *lagoons* of the sea-shore or the lake-shore. The south coast of Marthas Vineyard furnishes an excellent illustration of lagoons of this type. In times past, this shore was a succession of coves and small bays. But the water on this side of the island is so shallow that the waves, dragging heavily on the bottom, have pushed enough sand



LAGOONS, MARTHAS VINEYARD

before them to throw barriers across the coves, and shut them off from the ocean.[8]

Any good map of the United States or of Europe will show a multitude of wave-formed lagoons of this character. Those near the shore often have more the nature of sounds than of lagoons.[9] But as the coast, little by little, extends seaward, many of them now near the shore will ultimately be at a considerable distance inland.

Salt Lakes.—Salt lakes have no outlets, and for that reason they are salt.[10] Nearly all soil contains more or less mineral salts that are soluble in water. Even the hardest granites and igneous rocks contain a minute proportion of soluble matter. So when the water flows to the basin, it carries with it any soluble matter with which it comes in contact. If the lake or pond has an outlet, both the water and the salt flow off together.[11] If there be no outlet, however, the water is removed by evaporation, while the mineral salts, which cannot evaporate, remain in the basin. In time, the water becomes decidedly salt, and finally, a brine that will dissolve nothing more. After this, unless there is an inflow of fresh water, the salt sinks to the bottom, and forms also a wide margin of crusted salt along the shore.

Temperature and atmospheric moisture are also factors in the origin of salt lakes. High temperature and dryness of the atmosphere both promote evaporation, and doubtless there are regions, whose lakes are now fresh, that would become regions of salt lakes were the temperature and dryness to increase materially.

Although salt lakes have no outlets, it is not necessarily true that lakes without outlets are salt. As a matter of fact, there are many such lakes whose waters are almost as sweet and pure as when they fell from the clouds. Of this apparent contradiction there are two explanations.

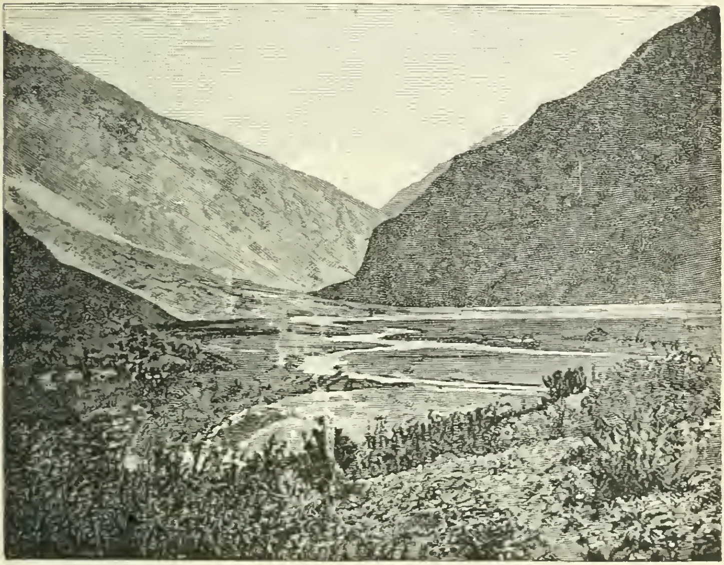
In the first place the lakes may be young. In this case, time only is required to change the fresh lake to one of brine, and the time will be long or short, according as the soil through which the feeders flow contains little or much soluble matter. In the Great Basin, west of the Rocky Mountains, there are several young lakes, whose waters are comparatively fresh,[12] situated almost alongside lakes of briny saltness. In the second place, all the soluble matter may have been leached from the soil at some prior time when the lake overflowed its basin. There are many such lakes in Canada and the United States. They are not salt, and unless their conditions of existence are changed they will not become salt.

There are certain lakes, mainly in arid regions, that are periodic in character. During the rainy season they may be of considerable size; they have no great depth, however, and in the dry season their waters evaporate, leaving in each basin a thick crust of salt. There are numerous small lakes of this character in the western part of the United States; some of those in southern Russia are of considerable area. Lakes of this kind are commonly called *playa lakes.* Commercially some of them are important on account of the enormous amount of salt they yield.

Physiographic Aspect of Lakes.—Lakes are the most transitory features of the earth's surface. Rivers and the various relief features of the earth are seldom entirely obliterated; but as time is reckoned a lake is the creation of a very brief period. Its life is almost ephemeral, and various forces are constantly at work to destroy it. Physiographic agents that have no effect on other features of the earth are often fatal to the existence of lakes.

Among the various agents, glaciers are, perhaps, the chief. Glaciers have been energetic factors in making lakes, it is true; they have also been quite as effective in

causing their destruction. The glacier blocks the channel of a river with ice or with gravel, and in a short time a lake is formed. Later it forces a passage through the obstructions made, and in a little while the lake has disappeared.[13] A few old shore marks and, perhaps, a delta or two are all that remain to tell the story.



A BURIED LAKE BASIN

The basin has been filled with sediments brought into it by the river

A change in the level of the lake-bed by elevation or by depression always produces great changes in the lake. Such a change may throw up a ridge so as to form a basin for a new lake, but it may also lower the land at the foot of the lake and destroy the basin of an old one. Long before the existence of the lakes whose remnants are now found in the Great Basin, a vast body of water covered much of

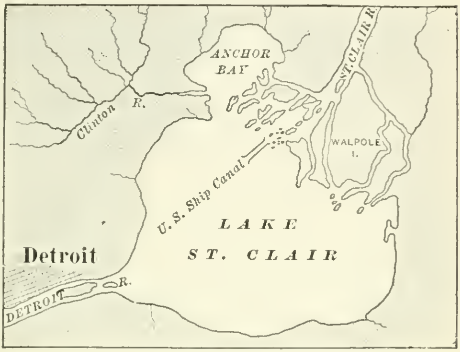
this region. But a change in the level of the basin occurred, and this, together with probable changes in climate, caused the great internal seas gradually to disappear.[14]

Rapidly growing vegetation is also a potent factor in the destruction of lakes. Vegetation has but little effect on deep lakes, but in the case of marsh lakes it has a great deal. The process is very simple: the roots, stalks, and leaves of the dead plants fill the basin until there is no more room for the lodgement of water. Usually the plant begins its growth at the edge of the lake and spreads toward the centre, gradually filling the basin, until a deep hole is all that remains. The struggle of the lake may be a long one, but in the end the vegetation conquers. Buried and partly obliterated lakes of this character are common in all coast plains and level lands. One near Goshen, New York, covering an area of about sixty square miles, has disappeared within recent times and most of its former bed is now cultivated land—the famous "onion fields" of the State.

Winds are sometimes very effective in the destruction of lakes, especially the lagoons along the seashore. The manner in which they operate is very simple; they merely carry enough fine rock waste into the basin to fill it.[15] The rock waste is piled upon the windward shore, and the latter advances, little by little, until finally it meets the opposite shore. The lagoon is filled, and at the same time an estuary becomes a part of the coast plain. Such instances are common on coasts that are swept by constant winds.

The foregoing are the most apparent agencies that contribute to the destruction of lakes; and although in many instances they operate continuously and systematically, they are confined to localities of comparatively small area.

But there are other lake-destroying agencies whose operations are carried on in almost every part of the earth; their manner may not be quite so apparent, but it is none the less effective. "Rivers are the mortal enemies of lakes."* The stream that flows into a lake bears in its volume more or less silt, which is promptly deposited in the lake basin, little by little filling it. With scarcely an exception, at the place where a stream enters a lake, either a delta or a bar is formed. This is clearly illustrated by the Volga, with its mazy delta; by the St. Louis, at the head of Lake Superior; and by St. Clair River, at the head of Lake St. Clair, and in the lakes of central New York.



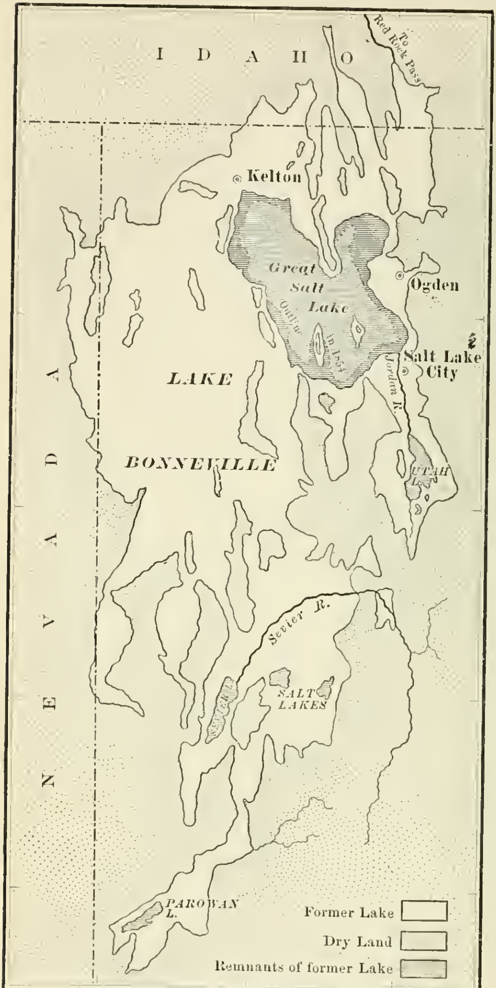
LAKE ST. CLAIR.

The mud flats at the head of the lake are the result of sedimentation.

The stream that flows out of the lake is equally destructive. It cuts away the rim of the basin, lowering the level of the lake until the water is nearly or quite drained. Not a few of the lakes that have disappeared from the earth have been destroyed in this manner.

A diminution in the rainfall sooner or later will also destroy a lake. The lakes and old lake-beds in the Great Basin illustrate this fact. Formerly Great Salt Lake and its scattered remnants—the latter, many of them, now dry—covered an area almost half the size of Lake Superior.

* Gilbert.



LAKE BONNEVILLE AND ITS REMNANTS

The area in white shows the former size of the lake; the small lakes south of Sevier River are practically dry.

At that time the level of the lake was nearly one thousand feet higher than at present. Afterwards, however, the rainfall decreased and, the indraught being less than the loss by evaporation, the lake dwindled to its present size.

In almost every part of the world are found old lake shore-lines high above the surface whose level they formerly marked.[16] In some instances they surround the sites of lakes that have ceased to exist; in others, of lakes that are reaching a period of old age. In any case

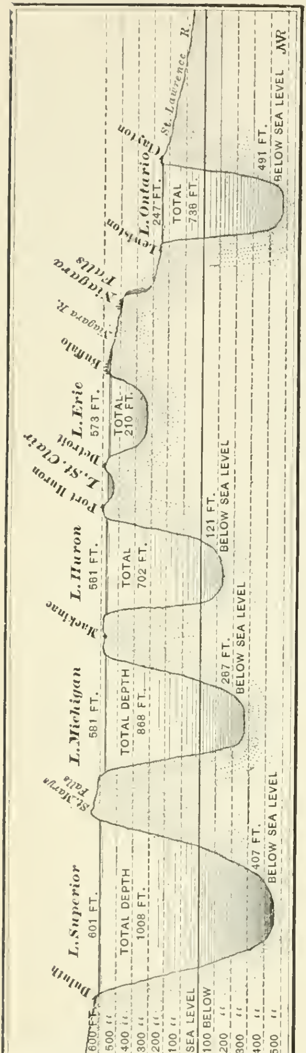
they serve to demonstrate that lakes are very transitory.

Many of the lakes of the United States have disappeared within very recent times. Sevier Lake in Utah has practically ceased to exist, and Tulare Lake, California, in twenty years has shrunk to less than half its former size. The finger lakes of New York have lost a measurable part of their area in the past fifty years, and the level of the Great Lakes has been materially lowered. In Lake Erie the diminution has interfered so much with navigation that a barrier across the outlet is now contemplated in order to raise the level of the lake.

Geographical Distribution of Lakes.—Lakes occur in all parts of the earth, but they are by no means uniformly distributed; as a matter of fact about ninety per cent. of them are north of the 40th parallel of north latitude.

With respect to glacial lakes this law holds almost universally true. The only exceptions are the few that are found in the southern Andes and the snow-clad summits of high plateaus and mountains. Most of them are situated in Europe and North America. In the latter division alone there are more than one hundred thousand glacial lakes. Why are the latter of rare occurrence in the torrid zone? Where in this zone would they occur?

Salt lakes are confined mainly to regions of deficient rainfall.[17] Why are they not common in regions of abundant rainfall? Most of them occur in the basin regions of North America and Eurasia; in the latter region there are several thousand. The Caspian "Sea," the largest lake in the world, is in this region; its surface is eighty-four feet below sea-level. Playa lakes are numerous in regions having a level surface and a light, periodic rainfall.



A SECTION ALONG THE GREAT LAKES

Most of the lakes may be grouped in systems which occupy lines of depression on the earth's surface. Two such systems are found in the Western and three in the Eastern Continent. The lakes of the Western Continent are chiefly in North America, and are embraced mainly in two systems. The largest and most important is the belt stretching across the northern part of North America. An arc of a great circle drawn from the city of Buffalo to Point Barrow passes through or near a chain of lakes that includes about the largest bodies of fresh water in the world. Find this chain on the map; describe the drainage and character of the lakes. Another system extends from the northern boundary of the United States southward through Mexico and the Central American States. Most of these are situated in a basin region; describe their drainage and character.

South America is remarkable for the absence of lakes

in any considerable number. There are playa lakes along the eastern base of the Andes, but the only lake of importance is Titicaca,[18] a large body of water near the summit of the Andes. Its surface is 13,000 feet above sea-level, and it is the highest large lake in the world. Do its waters reach the ocean?

In the eastern continent a wide belt of lakes, situated mainly between the 50th and 60th parallels, extends across Eurasia; what is their character? With respect to latitude their position corresponds pretty closely to that of the glacial lakes of North America. These lakes constitute the great majority in number, but they are of very little importance.

A second belt follows the high mountain-ranges that stretch from west to east across the continent. It embraces the playa lakes south of the Atlas Mountains; the glacial lake of the Alpine and Himalayan folds; and the multitude of playa and salt lakes in the basin region. Many of the largest and most of the important lakes of the continent are in this group. A third system in Africa follows the line of the eastern highlands, and therefore, unlike the other systems, extends north and south. Next to those of North America the African lakes are the largest bodies of fresh water in the world. Name and describe the four largest.

In one respect the Australian lakes are remarkable—almost every one is either a playa or a salt lake. Not a single one of any importance has an outlet to the sea. What does this indicate with reference to the rainfall of the continent?

Swamps and Marshes.—In some places the drainage waters cannot flow off, but remain about even with the surface, thereby forming what are variously termed *swamps, morasses, pocosons, bogs, and marshes.*[19]

Inasmuch as almost every condition of imperfect or embarrassed drainage results in marshy ground, it is evident that many different factors may bring about such conditions. For instance, the surface of the land may be so nearly a perfect level that the water cannot run off until it has completely saturated the soil. Such instances are very common: they occur in prairies and the flood plains of rivers almost without number. They are commonly, though not always properly, called *river terrace swamps*. Quite as frequently such morasses form at the mouths of rivers, where they form *delta swamps*, or *estuary swamps*.

In many instances the accumulation of vegetable matter results in swamps. Under ordinary conditions the leaves and twigs of forest growths quickly decay if they fall on dry ground and, as a rule, the products of decay are gaseous. Under such circumstances, therefore, no great amount of solid matter results from such decay. But if the ground be tolerably wet and rainfalls are frequent, there may be enough moisture to prevent complete decay. The vegetable matter gradually acquires a well-known condition, in which it consists of a fine, black slime and a mass of fibrous material called *peat*.[21] The accumulated matter prevents drainage and a swamp finally results. Most *woodland swamps* are formed in this way.

Not all woodlands become swamps, however, for the character of the vegetation nearly always has more or less to do in swamp-making. Several species of *sphagnum*, a kind of moss, are intimately connected with swamps. One of these water-mosses consists of very long, thread-like stems which, while dead at one end, are living and growing at the other. The dead portions do not decay, however; they simply accumulate, packing tightly together like an immense mass of sponge.

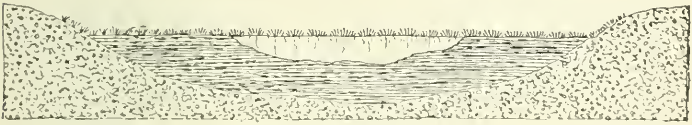
So, if the ground ever becomes wet enough for the water-loving sphagnum to get possession, the area will become a swamp, even if the accumulations of other vegetable material would not result that way. In time a hollow, a pond, or even a marsh lake will be entirely filled

EFFECTS OF VEGETATION

Swamp vegetation beginning at the shore, are extending outwards.

with the stems of sphagnum, thus forming *peat bogs* and *lacustrine swamps.*[22]

If sphagnum once obtains in an area, an absolutely level surface is not necessary for the formation of swamps. The sphagnum will make its way up a slope of four or five degrees and thus form a *climbing bog.* Instances of this kind are common in the Scandinavian Peninsula and also in Nova Scotia and the New England States.



EFFECTS OF VEGETATION

Swamp grasses and sphagnum have nearly filled the lake, and a quaking bog is beginning to form.

Sphagnous growths not only overwhelm shallow ponds and lakes, by filling their basins from top to bottom, but sometimes they operate against deeper waters. If the moss stems cannot find lodgement at the bottom of the lake they will float at the surface, spreading, little by little, until the surface is covered. The mat of sphagnum grows thicker

and broader, and is made firmer by pasty matter, that results from partial decomposition. In time the surface becomes firm enough to serve as the bed of a wagon road, or even a railway. But the surface never gets quite firm, and when one jumps upon it, or drives a wagon over it, the shaking is always perceptible. In this manner a marsh lake is changed to a *quaking bog*,[23] or *prairie tremblante*.

There are other species of vegetation [24] that have more or less to do with swamp formation—among them canebrakes. Canebrakes have long been associated with swamps, but usually as a *result*. As a matter of fact, canebrakes are not infrequently a *cause* of swamps. The roots of the plant, spread out just below the surface of the ground in much the same manner as does the sphagnum above ground, making finally a mat that almost wholly obstructs drainage.

Coast or salt marshes are confined to low coast plains. They are destitute of water mosses, but they contain other species of vegetation that are quite as effective. The first step in the formation of a salt marsh is an area of shallow, still water. Usually this results as soon as a sand-bar is thrown across a cove or estuary. Waves prevent the development of marine swamp, but in throwing up a bar they make the condition that is a foundation for the swamp. In a few instances sheltering headlands keep the water still enough for the growth of marine plants.

The next stage is the growth of eel grass, a plant with a long, slender blade. This takes root as soon as the cove begins to fill with sediment; it grows rapidly, and the half-decayed remains contribute not a little in filling up the marsh. But eel grass grows only when covered with salt water, and when the decayed vegetation, mixed with wind-blown rock waste, has filled the cove to low-tide level, it perishes. After a time the marsh passes a step

higher in its formation, receiving layer after layer of sediment that build its surface to a level where it is awash at high tide only.

By this time true salt-marsh grasses, reeds, rushes, and tules obtain possession. These species thrive only when their roots are covered with salt water at short intervals. They accumulate until the level of the marsh is built above the level of the highest tides. When this stage is reached turf grasses gradually take the place of salt-marsh grasses, and the marsh becomes meadow land.

Another plant active in swamp-making is the mangrove-tree. This tree thrives only in salt water. It propagates itself partly by upshoots from the enormous mass of roots that trail under water, and partly by seeds. The growth and spreading of mangrove roots and trunks is so great that coast outlines are extended rapidly and fringing barriers are formed as well. In Florida mangroves and corals are yearly adding measurably to the swamp-land surface of the State.

The tundras of the Arctic coast plain furnish an interesting example of the combined action of ice, fresh water, salt water, and moss. These shores are almost constantly covered with ice. Not only are they inundated by tidal waters, but also by stream waters. The mouths of the streams are frozen, and the flood water, finding its channels blocked with ice, spreads broadcast over the surface.

During flood seasons the stream waters are filled with sediment, and this is spread over the plain. Moreover, it furnishes sufficient nutriment to heavy growths of coarse moss, and the latter, in turn, not only holds the sediment in place, but it also in no small degree prevents the melting of the ice. As a result, this plain is a perpetually half-frozen morass, and probably the most inhospitable region on the face of the earth.

Physiographic Aspects of Marshes.—Notwithstanding the fact that the area of marshes and swamp is comparatively small, it is probable that much of the land surface of the earth has been a marsh or a swamp in some period of its existence. In a way marine marshes may be considered as land at an intermediate stage between submergence and elevation. Hence, volcanic areas excepted, the shallow lagoon, the eel grass swamp, the barren mud flat, the salt grass marsh, and the turf-covered plain is each, in turn, an incident in the final elevation of a body of land above sea-level.

Along the coast of the South Atlantic States one may find the lagoons and the eel grass swamps; along the shores of the Gulf there are, in addition, very broad mud-flats;[25] in the bay of San Francisco and the adjacent waters are many square miles of salt-grass and tule marshes; and almost everywhere beyond the reach of tidal waters there are the turf-covered plains.

The range of fresh-water swamps may not be quite so great, but economically they are quite as important as the marine marshes. Their evolution and physiography, moreover, is rather more complex than the development of marine marshes, but in two respects they are alike—namely, *vegetation makes them and, in the long run, it destroys them.*

Vegetation may, and usually does, operate to create swampy conditions, but the process of destruction does not differ from that of creation. The accumulation proceeds until the surface is lifted to a level where the ground waters may flow off.

Cultivation destroys swamps, and the process of destruction is simple. Most grains and food-stuffs require a comparatively dry soil, and the very act of ploughing creates drainage channels in which the water flows off. Where

ploughing has not been sufficient, ditching and underdraining accomplish the same results.

But swamps themselves exert not a little influence on vegetation and its distribution. Many species of tree and shrub that thrive in moist or dry soils perish if the soil be saturated. Thus, a swamp once obtaining in a woodland area, it is a question of time only before many, possibly all of the forest species disappear. In almost every fresh-water swamp the most marked features are the stumps and trunks of dead trees—a result of the development of swampy conditions. What species of evergreen thrives in swampy lands?

Economic Value of Swamps.—Swamp, marshes, and bogs, although practically uninhabitable for human beings, have had a very far-reaching effect in the development of civilization. In evidence of this the results of the coal-beds may be cited. The enormous development of commerce and manufactures is due almost wholly to the coal-fields of the world, and these almost without exception are the swamps and marshes of prior geological ages.

The swamps of the present time are the most productive areas to be drawn upon in the future. The soil possesses great depth, and its nutrient qualities are exceedingly great. Swampland crops themselves are of no little importance, and the rice-swamps probably supply food to a greater number of people than all the other grain-fields in the world. Incidentally, the world's supply of cranberries comes mainly from swamps, and the peat-bogs furnish fuel to not far from fifty millions of people.

The Movement of Rock Waste.—In this and the preceding chapters it has been shown that the higher parts of the land are almost everywhere crumbling and wasting away under the action of water in one or another of its different forms. Rain, snow, ice, running streams, and

even the winds are factors that are unceasingly active, and their legitimate work is to wear away the land and transport the material removed to sea-level.

On the steeper slopes, as a rule, the rock waste is coarse, the fragments sometimes weighing many tons. On its way downward it is broken and worn in various ways until, at sea-level, it is very fine. Much of it is also mingled with the remains of vegetation, and takes the character called *soil*.

The soil is deposited in river valleys in the form of flood plains, delta plains, estuary plains, and coast plains. Review briefly the formation of each. Some of it is arrested by obstructions along its downward journey and, filling the depressions in front of the barriers, forms lacustrine plains. Name several examples. Explain how all these physiographic processes affect the habitability of a region.

The waste of the old land is the material of the new.

QUESTIONS AND EXERCISES.—Study any lake or pond near which you live and classify it as marsh, glacial, swamp hole, or salt; make a map of it.

Note whether a coast plain is present, or whether the water-level is at the foot of cliffs or banks.

If there is a fringe or belt of coast plain what does it indicate concerning the present and the former size of the lake?

Note whether or not the border is marshy and thickly covered with vegetation, or whether it is strewn with large bowlders.

In what, if any, part are the waters muddy? From this determination endeavor to find where the sediment is chiefly deposited.

From the foregoing write a description of the body of water.

From the diagram of the Great Lakes, together with a good map, p. 176, prepare a description of these lakes. What will be the effect of the recently completed ship canal at Chicago, on the level of Lake Michigan?

What would be the effect on the character of the water were the basin of the Caspian Sea to fill until it overflowed?

If the basin of the Black Sea were elevated twenty or thirty feet what would the water be, salt or fresh?

Mention some of the benefits resulting from the Great Lakes of North America, with reference to commerce, industries, and climate.

Which of the two Great Lakes may be regarded as a single body of water? Why?

The level reach of land in the illustration, p. 171, was formerly a lake; explain how it became the flood plain of a mountain stream.

From any convenient source of reference write a description of Death Valley, California, or of the Dead Sea, Syria.

From the section of the marsh lakes, p. 166, prepare a description of them, concerning their depth, altitude, and navigability.

COLLATERAL READING AND REFERENCE.

RUSSELL.—Lakes of Nevada, *Physiography of the United States*, pp. 101–130.

LE CONTE.—Elements of Geology, pp. 80–82, 580–581.

SHALER.—U. S. Geol. Survey, An. Rep't, 1800.

NOTES

[1] There is no distinction between a lake and a pond, except the very indefinite one of size.

[2] Lakes are sometimes formed, however, in places where a steep slope joins one that is very moderate. Examples of such lakes occur in the eastern slope of the Scandinavian Peninsula and in Nevada.

[3] Marsh lakes are rarely more than a few feet in depth. They are seldom navigable, and commercially they are of but little importance. In Europe many such lakes have been drained in order to make cultivable land of their beds. There are several instances where such basins are filled with water and used for fish culture for a period of several years, and then drained and cultivated for a like period.

[4] Occasionally lakes are formed on mountain-slopes by the agency of landslips, but they are seldom long lived. Sometimes they break through the material that blocks their overflow, but more commonly the outflowing water cuts a channel through it deep enough to drain the lake to the bottom.

[5] "Walled" lakes are common in Iowa, Minnesota, and Dakota. So regular are the walls of their shores that for many

years it was commonly believed they were artificial and were built by a prehistoric race of people. As a matter of fact, however, the walls are the work of ice. In severe winters these lakes freeze nearly to the bottom ; but inasmuch as water increases in bulk when it freezes, the ice, in expanding, pushed the bowlders shoreward. Time and time again this process was repeated until the rocks were pushed back to a position where the resistance of the earth back of them was equal to the pushing force of the ice.

[6] In scraping out these basins not the ice itself, but the fragments of rock held at the bottom, form the cutting tool.

[7] There are several instances in which flowing lava has blocked up a river channel and formed a lake. In at least two places the Columbia River was thus blocked, and the high-water marks of the lakes formed are still plainly visible. In each instance, however, the river succeeded in recovering its channel and the lakes were therefore drained. Accidental lakes, resulting from the blocking of a river channel by coulées of lava, are common in volcanic countries. Still another accidental lake is the *crater* lake, which is merely an old volcanic crater filled with water. Crater Lake, in Oregon, and Lucrine Lake, in Italy, are examples of such lakes. The former is about 2,300 feet deep and is a wonderfully interesting body of water.

[8] Not only have coves of the sea-shore been shut off by bars, thus forming lagoons, but the same process has been carried on along the shores of lakes. Such lagoons are in process of formation at the head of Lake Superior, Lake Erie, and Lake Ontario. In each case, however, the formation of the lagoon is not yet complete, owing to the fact that the current from the river is still able to keep a channel open.

[9] Albemarle and Pamlico Sounds are examples, and they remain as sounds for the reason given in the preceding note. In other words the sound is often an intermediate stage between a bay and a lagoon.

[10] There are a few small salt lakes having outlets, but none of importance. They are saline because of salt springs within their basins. Not all so-called salt lakes contain common salt, however ; in many various alkaline substances are found.

[11] Near the City of Mexico formerly there were several lakes that overflowed into a fourth. The latter is salt, the others not drained are fresh. Utah Lake overflows into Great Salt Lake through

Jordan River; its waters are fresh. Lake Chad, in Africa, is normally without an outlet. Occasionally, however, in seasons of unusual rains, it overflows into the Libyan Desert. This occasional overflow is sufficient to keep its waters fresh. The waters of the Caspian Sea are kept moderately fresh by a similar process. On its eastern border is a gulf, the Karabogas, connected with the main body of the lake by a narrow strait. The waters of the gulf are very shallow, and so great is the evaporation, that a four or five knot current is constantly flowing into it from the main body. From this inflow about 250,000 tons of salt are deposited daily. Now, if this amount of salt were left dissolved in the lake the latter would sooner or later become a saturated brine. But because of this separation and deposit of salt, the waters have not become perceptibly salter, in the time since measurements have been made.

[12] It seems a contradiction of facts to assert that a salt lake may become fresh by a process of drying up; nevertheless this has been the history of many lakes. During a long-continued period of deficient rainfall, a lake may dry up, leaving its mineral salts as a deposit upon the bottom. In time the winds cover this saline crust with a thick layer of fine soil; and when the lake again begins to fill, its waters are fresh. Pyramid and Winnemucca Lakes in Nevada are illustrations; their waters are comparatively fresh.

[13] Lake Agassiz, a body of water considerably larger than the five great lakes, formerly covered a large part of the valley of the Red River of the North. The destruction of this body of water was caused probably by glacial action. It had several outlets, one of which was the present channel of the Minnesota River.

[14] This lake preceded any of the lakes now in the Basin Region. and was older even than the Uinta Mountains. The bed of the lake seems to have been lowered, and this, in part, was probably one factor in its destruction.

[15] It is not unlikely that Lake Mœris, in Egypt, was destroyed by winds. It was situated a few miles southwest of the Nile delta and disappeared within historic times; but until within a few years its exact position was not known. In this region the movement of wind-blown rock waste is incessant, and the amount moved in even a few days is enormous. Former canals across the Isthmus of Suez, one after another have been filled by rock

waste, and there is every appearance to suggest that the isthmus itself was formed largely through æolian agency.

[16] The old shore lines of Great Salt Lake are still a marked feature, and, excepting the few places where they have been obliterated, they have been surveyed throughout the entire circuit of the lake. Old shore lines have been found above the present level of Lakes Titicaca and Maracaibo, and also above the level of the lakes of the western part of the Great Basin. Two old shorelines of Lake Ontario have been found in New York, one of which, the "Ridge Road," may be traced along nearly the whole extent of the southern shore. In time its level has been somewhat warped and it has now a grade of one or two feet per mile.

[17] In many instances the carbonates of alkaline metals are present in such quantities that the waters of the lake are strongly alkaline. Many of the lakes of the Great Basin are alkaline.

[18] Lake Maracaibo is a lagoon or "clover-leaf" bay, rather than a lake of ordinary character.

[19] It is difficult to draw the line between marsh lakes and swamps on the one hand, and quite as difficult to distinguish between the latter and meadow lands on the other. The difference is practically one of degree. A lake or a shallow lagoon passes through all the intervening stages.

[20] In many instances the emergence of underground waters to the surface, by percolation (see illustration, p. 133), causes swamps. The various *bolsas* on the coast plain between Los Angeles, California, and the ocean are formed in this manner.

[21] It is well to bear in mind that peat is not a *plant*, but a *condition of imperfect decomposition* that, under certain conditions, almost all vegetable tissue may assume. The softer and more soluble parts of the tissue, which have been changed to a black slime, are really a mixture of nearly pure carbon and hydrocarbons; the wood fibre remains. It is likely that the incorrect popular notion has arisen from the fact that nearly all the peat used for fuel is derived from species named.

[22] Although all lacustrine swamps are old lakes that have been destroyed by vegetation, not all of them become peat-bogs. In many instances the lake is situated north or south of the latitude in which sphagnum thrives. The peat-bogs of Ireland are historic, but they are not more extensive than those of the

Danube. They occur in nearly every country in which sphagnum grows.

[23] Quaking bogs are very common in the swamps of the South Atlantic States. Usually the mat of sphagnum spreads from the margin toward the centre, but in many instances patches of the plant accumulate in the open water, forming islands. Generally the insular patches are attached to the bottom, but not infrequently they float hither and thither. In time they spread marginally until the surface is finally covered. The mat of accumulated sphagnum receives more or less earthy matter and becomes a tolerably firm surface. In California one of the lines controlled by the Southern Pacific Company was built across a quaking bog a distance of several miles. It finally caved in, however, engulfing several cars of a freight train.

[24] The various species of rush, flag, reed, and sweet briar are associated with swamps and contribute not a little to their formation. The wild grape and several species of wild smilax are also abundant in swamps. These species, however, are found mainly south of the latitude in which sphagnum thrives.

[25] The mud-flat stage is always present; it is merely the area or belt that is uncovered at low tide. If the slope is gentle this belt may have considerable width—and this is the case along the coast of the South Atlantic States and the shores of the Gulf. Along shores swept by fairly high tides the mud-flat belt is usually wide.

CHAPTER XI

OCEAN WATERS AND THEIR MOVEMENTS: WAVES, TIDES, AND CURRENTS

Almost all the phenomena connected with the wasting of the land, with climate, and even with the existence of life, in one way or another depend on the sea. In at least two ways the sea differs from other bodies of water. It is many thousand times the size of the largest body of fresh water and, two or three inland lakes excepted, its surface level is lower. Practically the sea supplies the land with fresh water, and because of its lower level, almost all the waters of the land sooner or later flow back into it.

Sea-water is briny and bitter; doubtless it has always been thus, but inasmuch as the stream waters flowing into it are constantly dissolving mineral matter from the rock waste and carrying it to the ocean, the amount in the latter is constantly increasing. Every one hundred pounds of sea-water, on an average, contains about three and one-half pounds of saline matter; most of this is common salt, the remainder being chiefly lime and magnesia. The percentage of mineral matter varies. In localities where evaporation is rapid, the proportion of salt is larger. Thus, in the Red Sea[1] it is more than four per cent., while in the Baltic Sea it is less than one-half as great. It is somewhat greater in tropical than in polar regions.

Bulk for bulk, sea-water is heavier than fresh water. A cubic foot of fresh water weighs about 1,000 ounces; on

THE SEA: FAIR-WEATHER WAVES.

account of its mineral matter the same volume of sea-water weighs at least thirty-five ounces more. Temperature also affects the density of water; if 1,000 cubic inches of water at the freezing-point be heated to the temperature of a hot summer day, its volume will be increased seven or eight cubic inches. The differences in temperature and density have far-reaching results; for upon these variations the general circulation of the waters of the sea in part are due.

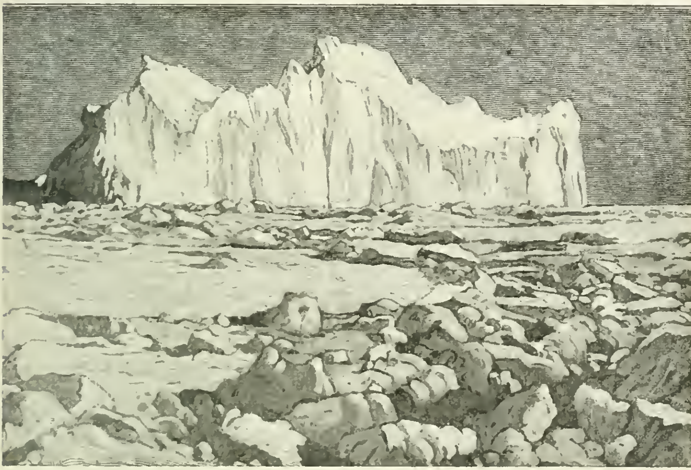
The temperature of the sea varies with both latitude and depth. In general, the surface waters of equatorial regions are warmest, and in the broader extents of the sea their temperature is not far from 26° (79° F.). Toward the poles it gradually falls, and in polar regions it is rarely much above the freezing-point. The variation of temperature with latitude is by no means uniform, however, for in various places warm water dragged by the "skin friction" of winds is frequently found in high latitudes.

With relation to depth the variation is remarkably uniform. In low latitudes the bottom temperature of deep water is a degree or two above the freezing-point of fresh water; in polar latitudes, a degree or two below it. In shallow waters and land-locked basins, however, the variations in temperature are usually very irregular. Thus, the entrance to the Gulf of Mexico is blocked by a submarine ridge whose crest is 1,200 feet below the surface, and because of this, water whose temperature is lower than that of the 1,200-foot level cannot enter the Gulf. But even at a depth of 12,000 feet, the temperature varies but little from that of the 1,200-foot level.

The freezing temperature of salt water is lower by two or three degrees than that of fresh water, the difference depending mainly on the amount of mineral salts in solution. The ice of the sea is therefore formed in high lati-

tudes, where the temperature is much below the freezing-point.[2]

Sea-ice takes various forms.[3] The nearly level and narrow shelf that in polar regions forms along the shore, and skirts almost its entire extent, is called the *ice-foot*. Any considerable extent of undisturbed or unbroken ice forms an *ice-sheet* or *ice-field*. When on-shore winds become so strong that the ice-field is crushed and piled up against the



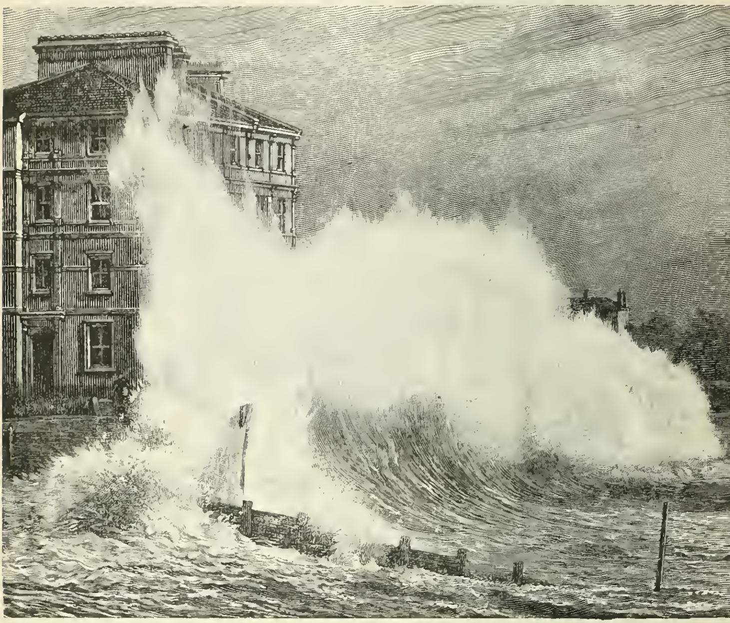
ICE OF THE SEA: FLOE, PACK, AND BERG.

shore, it forms *pack ice*.[4] Detached masses floating about constitute *floes*; finely broken ice floating on the surface constitutes *sludge*.

A small part of the ice is caught by currents and winds, and carried into warmer latitudes, where it finally melts. By far the greater part, however, never leaves polar regions; possibly in a few instances it accumulates, but most of it melts during the brief polar summer. A certain amount of ice certainly floats into temperate latitudes, in

the form of *icebergs*, but this ice is not born of the sea; it is fresh water ice that is formed on land, and, in the form of glaciers, moves down the slopes until it breaks off.[5]

Waves.—The alternate rising and falling of successive ridges of water form waves. They vary in size from the



STORM WAVES: SURF BREAKERS.

tiny ripples made by a summer breeze, to the huge billows that toss the largest ships.[6] Every body of water upon the earth is swept by waves, and these are caused by the friction of the air against the surface of the water.[7]

The motion of the water of the wave is simply up and down, with a possible rotatory movement; and if the wind ceases for a moment, the theory holds true. Under a

strong wind, however, the top of the wave is pushed forward, and if the gale be very strong it breaks into foam, forming "white caps" and "scud." Before the strongest storm-winds not a little water is blown into spray, and the whole surface of the ocean is covered with foam.

When waves roll in upon a shallow coast their motion is also modified. The moment the bottom of the wave touches ground it begins to drag. The top of the wave, on the contrary, not being impeded, advances more rapidly, and finally *combs* or falls forward, making *breakers*. The water and foam that flow upon the shore constitute the *surf*.

The distance from the shore at which waves begin to comb depends partly on the depth of the wave, and partly on the depth of water along the shore. Ordinary waves rarely exceed three or four fathoms in depth, and therefore do not comb until they are within a few rods of the shore. Along certain shores of the Indian Ocean, on the other hand, where the coast waters are shallow and the waves are deep, the latter begin to comb at a distance of three or four miles from shore.

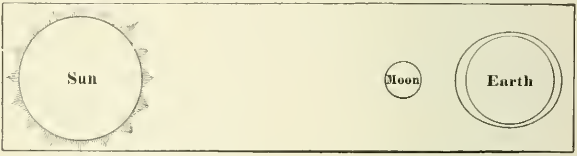
For the formation of the highest and largest waves, a deep, open sea is required, and in general the largest waves are found in the broadest expanse of water. In calm weather, the waves of the open sea are from six to ten feet in height; their breadth is about ten times the height.

With a wind of twenty or thirty miles an hour, the height of the wave is somewhat increased; its breadth is materially greater, and the largest steamships pitch considerably as they ride over them. With the wind at sixty or eighty miles the breadth of the wave is increased to about two thousand feet; its height may reach twenty or thirty feet, and its progressive velocity may reach forty miles an hour.

It is a common belief that the waves run highest when the wind is at its maximum velocity. This is not the case, however; they do not reach their greatest height until the lull of the wind;[8] then they sometimes roll to a height of forty-five or fifty feet.

The force with which waves strike an opposing surface is greater than is generally imagined. Measurements on the coast of Scotland, show that ordinary calm-weather waves have a striking force of six hundred pounds per square foot; that of the heaviest storm-waves is about ten times as great.

In navigation it is found that the chief damage from storm-waves is due to the battering that the lighter woodwork above deck receives.[9] In recent years the old custom of spreading oil on the surface to the windward has been revived.[10] The oil covering the water presents a surface that offers comparatively little friction to the wind. As a result the waves, although rolling high, no longer



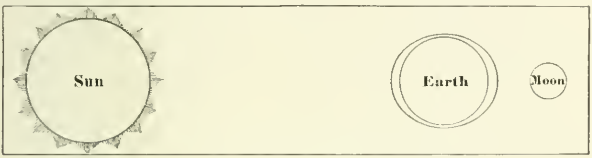
THE TIDE WAVE: MOON IN CONJUNCTION

break upon the vessel. The latter, therefore, is often enabled to withstand storm-waves that otherwise would demolish everything above her decks.

Notwithstanding their tremendous energy, waves are superficial. The effects of ordinary, calm-weather waves do not extend more than a few feet below the surface; the fiercest storm-waves do not reach more than two hundred feet below the surface.

Tides.—The alternate rise and fall of the sea-level twice a day is a phenomenon familiar to everyone who has visited the seashore. For six hours the level of the water, little by little rises, overflowing the shore and filling the river estuaries. For a few moments, the water is stationary, and then for about six hours it falls—ever repeating, never ceasing its oscillations.

Excepting certain estuaries and bays, neither the high nor the low water level varies much throughout the year. As the level rises and the water flows in upon the shore,

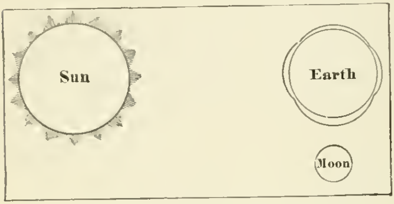


THE TIDE WAVE: MOON IN OPPOSITION

the tide is *flood*; as it recedes it is *ebb*; its highest level is *high water*, and its lowest *low water*. During the few minutes at the turn of the tide it is *slack water*.

This rise and fall of water is ascribed to the attraction of the sun and the moon; in its nature, the movement of the water is practically a wave several thousand miles broad. Both the sun and the moon attract the earth. The solid portion of the earth being rigid, however, does not perceptibly bend or yield; the water envelope, on the contrary, is drawn into the elongated form,[11] giving the appearance of two wave-crests, one on each side of the earth. No matter whether the sun and the moon are on the same side, or on opposite sides, their combined attraction will produce the same results. If, however, they have the position, so that they pull at right angles, four tide-waves will be formed—two of the sun and two of the moon.

In most of the Northern Hemisphere, where the great land masses interrupt the progress of the tide-waves, the solar tides are merged into those of the moon. Only in the broad expanse of the ocean, in the islands of the South Pacific, are they distinguishable. When their effects are added to or subtracted from the lunar waves, however, the difference is considerable. Thus, at new and full moon, when the pull is exerted in a straight line the tides are somewhat higher at flood and lower at ebb; these are the *spring tides*. When the attraction is exerted at right angles they are *neap* tides. In some instances the spring tides are twice as high as the neap tides.



THE TIDE: MOON IN QUADRATURE

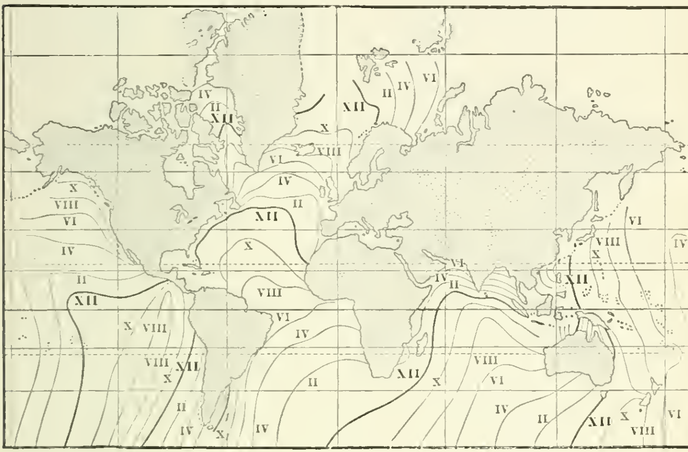
Thus it seems that the moon by its attractive force lifts the waters of the sea into two great waves. Moreover, as the moon revolves around the earth, these waves are each dragged around at the same time, in much the same manner as though they were fastened to it, each making a passage in about twenty-eight days.

But while these waves are making each its revolution, the earth at the same time is turning on its axis, every twenty-four hours. The *daily* motion of the tides, therefore, results from the earth's turning on its axis. Every point on the earth, accordingly, *overtakes and passes* the two waves daily, very much as though it were slipping under them.

If the surface of the earth were covered with a uniform depth of water, the direction of the tide-waves would be from east to west. As a matter of fact, the position of the

continents prevents any such uniform direction. Every mass of land is an obstacle in the path of the advancing wave, and inasmuch as the latter cannot sweep over a continent, it must pass around it, or be checked.

Only in the broad, open waters of the Southern Hemisphere do the tides move in their theoretical direction from east to west. In the North Atlantic the wave is turned



CO-TIDAL LINES

The lines show the position of the crest of the tide-wave for each two hours.

to the northward, and, entering the Arctic Ocean, it is diverted to the eastward.[12]

The height of the tides is also affected by the land masses. In mid-ocean the difference between high water and low water is scarcely three feet. Along the coast of the United States it varies from four to ten or twelve feet. From New York to Savannah spring tides are about five feet, and neap tides about four feet. In the Gulf of Mexico the rise and fall is only about one-half as great;

along the Maine coast it is ten or twelve feet; and at Sitka, Alaska, from twenty to thirty feet.

The great difference is due chiefly to the shape of the shores. If the tide-wave faces a V-shaped estuary the advancing body becomes constricted by the narrowing shores. Not being able to spread out sideways, it is therefore increased both in depth and velocity. In Minas Basin, at the head of the Bay of Fundy, at times the water advances as a solid wall twenty or thirty feet high. The piling up of tide-waters in the form of a wave is commonly called a *bore*. It is a marked feature in the Amazon, the Ganges, and the rivers of the China coast. It is also noticeable in many of the estuaries of the British Isles. The spring tide in Bristol Channel is sometimes forty feet.

In many instances the shape of the shore is such that the waters of the advancing tide are separated by an island lying near the shore, again uniting in the narrow strait between the mainland and the island. As a result eddies and dangerous whirls are formed. Thus, at Long Island the advancing wave is divided, one part entering New York Bay, the other, Long Island Sound. The two currents meet in the narrow Hell Gate, or "whirling strait." The Maelstrom, an eddy formed by the Lofoten Islands, off the coast of Norway, is a similar current.[13]

Ocean Currents.—Throughout the greater part of its extent the sea is traversed by *currents* that flow in definite directions with a fairly uniform velocity. The water of an ocean current has an energy of its own, and its motion is practically the same as though it were flowing from a higher to a lower level. There are other instances, however, in which the movement is almost entirely caused by the wind, the direction being wholly a result of the wind. The wind-blown waters are called *drifts*. Currents are deep, sometimes extending to the bottom; drifts, on the

OCEAN CURRENTS

other hand, are superficial. The current may gradually become a drift, and a drift may become a current.

The winds, and the unequal heating of the waters in equatorial and polar regions are thought to be the main causes of the general movement of ocean waters; the winds and the rotation of the earth on its axis are the chief factors that make them currents and determine the direction of their flow.[14] The water in equatorial regions receiving the vertical rays of the sun is heated to a higher temperature than the water in higher latitudes. Being expanded a flow toward polar regions occurs. At the same time cooler water flows toward the equator in the form of an undercurrent. Thus a constant circulation is taking place—a surface movement from equatorial to polar and an undercurrent from polar to equatorial latitudes. This general movement is modified by the winds—and undoubtedly by the rotation of the earth.[15]

In equatorial latitudes the prevailing direction of the wind is toward the west, and this gives the waters a westerly movement. A flow of water, nearly 1,000 miles broad, called the *Equatorial Current*, is the result, and, except at the places where it is interrupted by the continents, it girdles the earth. Its flow is scarcely more than a drift, and its rate is about ten or fifteen miles per day. Most of the warm currents of high and temperate latitudes are branches of it.

The Atlantic part of this current is divided at the eastern angle of South America. The southern branch flows along the eastern coast of this grand division for nearly 2,000 miles; what is its name? Gradually losing its energy it becomes a drift, and finally it returns to the equatorial current. Describe the course of the northern branch; what is its name after it emerges from the Caribbean Sea? The Pacific part of the Equatorial Current is

more than 9,000 miles long. At the edge of the Eastern Continent it is again divided; what is the name of the northern branch? of the southern? Describe the circuit of each. In the midstream of the Equatorial Current is found a narrow belt of water flowing in the direction opposite that of the main stream. It is called the Equatorial Counter Current; no satisfactory explanation for it is known.

The *Gulf Stream* is by far the most important of the currents of the Atlantic Ocean; why? Its sources are in the Caribbean Sea. A part of its volume flows through Santarem Channel; a greater part is gathered into Yucatan Channel; a small but measurable part is drawn from the Gulf of Mexico. These branches unite in Florida Strait, and here the stream as a definite current begins.

At Florida Strait its velocity varies from three and one-half to five and one-half miles an hour.[16] To the northward it gradually decreases until, off the Labrador coast, it ceases to have any motion of its own; thereafter it is a drift dragged by westerly winds.

The Gulf Stream is not only the swiftest of ocean currents, but it is also the warmest. Off the Florida coast its summer temperature is 30° (86° F.), and even near the Greenland coast it is twenty or thirty degrees (F.) warmer than the surrounding waters. Contrary to common opinion, it is not a shallow current. As a matter of fact, from Florida Strait to Cape Hatteras, it extends to the bottom of the ocean. Its drift is pushed northward and eastward, and much of it forms a circuit returning to the Equatorial Current. A considerable volume, keeping northward, finds an entrance to the gulfs and bays of western Europe, reaching even to the north coast of Norway.

The *Kuro Siwo* is the Gulf Stream of the Pacific. Some of its waters issue from the Bay of Bengal, but the

greater part of its volume passes among the Malaysian Islands. Thence it flows along the eastern coast of Asia. Off the Japan Islands it becomes a drift, and its waters are then pushed by the prevailing winds toward the North American coast, performing an oval-shaped circuit like that of the Gulf Stream.

The Kuro Siwo is not only a much feebler current than the Gulf Stream, but it is a cooler stream as well. Its summer temperature rarely exceeds 22° (72° F.), and its winter temperature is not far from 17° (63° F.). In summer it extends as far north as the Kuril Islands; in winter it scarcely reaches the Japan coast. Recent surveys show that, contrary to common opinion, no part of the Kuro Siwo enters the Arctic Ocean through Bering Strait. In a few instances only has a setting of water into the strait been observed, and these have resulted from strong southwesterly winds. The prevailing movement in Bering Strait is a feeble flow from the Arctic Ocean.

It has been definitely ascertained that much of the circulation of the colder waters of the ocean takes the form of undercurrents, but no survey of an undercurrent has yet been made. Two very definite surface currents of water have been observed, however, and their position is fairly well known. These are the *Arctic Currents.* One of them flows southwards along the east shore of Greenland, finally turning into Baffin Bay; the other flows on the west shore and, emerging into the Atlantic, meets the Gulf Stream off Newfoundland.

Off the coast of Cape Hatteras, almost in the track of the Gulf Stream, is an adverse current known on pilot charts as "*Little Hell.*" It is marked by heavy, choppy waves, and persists, even in the face of a strong southerly wind. Its waters are cold, and it is thought to result from the rising of an arctic undercurrent to the surface.

The *Antarctic Current* is the chief movement of cold water in the southern hemisphere. It is a drift rather than a definite current, however. Its waters are several degrees cooler than those with which they finally commingle.

Economy of Ocean Currents.—One of the chief and most important effects of marine currents is the equalizing of the temperature of ocean waters. Without this interchange the heat of equatorial waters would sooner or later become fatal to many forms of life, and the polar ice-caps would intrude far into temperate latitudes. The more practical effects are seen by comparing the coast of Labrador with that of the British Isles, in the same latitude. The harbors of the former are blocked with ice for five or six months of the year; the latter is open the year round. The former is bathed by cold waters; the latter by the drift of the Gulf Stream. The port of Hammerfest, situated within the Arctic circle, is an open harbor free from obstructive ice all the year round. It is very doubtful if warm currents have any perceptible effect on the temperature of a region at any considerable distance from the coast, but that they keep the coast free from ice is beyond question. How does this affect commerce?

Evaporation is very great along the courses of warm currents and the moisture borne with the wind adds no little to the rainfall of the regions. When the moisture is condensed the latent heat set free adds warmth to the region. Cold currents have a chilling effect on the air, and if the latter has much moisture it is apt to take the form of fog. The Newfoundland and Labrador coasts probably get their dense fogs in this way. Ocean currents thus are indirectly factors in climate.

Sargasso Seas.—Within the ovals formed by the branches of the Equatorial Current and their drifts there

are extensive accumulations of marine plants. These were named by Spanish navigators *Zargazzo*, or grassy seas. The accumulations have been sometimes attributed to the eddying motion of the current and its drift, but of this there is little or no evidence. Calm water is necessary for the growth of these species forming the accumulations, and they occur most frequently in such localities.

Physiographic Effects of Oceanic Movements.—So closely related to one another is the work of waves, tides, and currents, that their physiographic effects cannot well be separated one from the other. In general the work of waves is both destructive and constructive—they not only tear away coasts, but they build them as well. On the other hand, the work of tides and currents is mainly transporting—they carry material from one place to another. Although waves act only at the surface, their work is none the less effective, and throughout the whole extent of coast one or the other of two things is constantly going on—material is either being removed from the shore or else it is being added to it.

The rugged outlines of coasts to a considerable extent are results of wave action. The softer parts are worn and broken, while the harder portions that remain largely contribute to the frayed appearance of the coast.[17] At first the harder rock projects in the form of long arms; then these are broken, leaving a multitude of rocky islets.

Along the coast of the South Atlantic States, the effects in places are still more noticeable. The shores of Cape May, New Jersey, are wasting away at the rate of several feet a year, and those of Charleston Harbor require almost constant repair, so destructive is the incessant pounding of the waves.

On the east coast of England, owing both to waves and swift tidal currents, the yearly waste is considerable,

and since the time of Henry VIII. a belt about one mile in width has been shorn from the Kent coast.[18] Along the west coast of Scotland, and especially among the Hebrides Islands, are many thousand rocky islets rising from the sea like spectral watch-towers. They are all that remain of a former coast as witnesses of the destructive force of the waves.

As its name indicates, a cliff-girt coast is one that is bordered by steep or by vertical cliffs. The chalk cliffs of Dover, England; the cliffs at Newport, Rhode Island; and almost the whole extent of the California coast are examples of this type. Generally there is a narrow strip of sandy beach between the cliff and the water's edge, but sometimes this is absent. In every case the cliffs are shaped by the action of waves. On account of a slow subsidence of the coast, the sea has encroached on the land, and little by little, the waves have undermined and battered down the shores.

The constructive and building power of waves is finely shown along the coast of the South Atlantic and Gulf States and that of the Netherlands, the most noticeable feature of which is the multitude of spits, barrier beaches, and islands that border it.

In the building of shores not a little depends on the position and direction of tides and local currents. If the latter strike the shore broadside, or at right angles, the bars and spits take the shape so common along the Gulf coast. On the other hand, if they impinge upon the shore obliquely, the sand and sediment are caught by the swirl of the current, and deposited in curved forms variously known as *sandy hooks*.

Forms of this character are the rule along the Massachusetts coast. Cape Cod, Monomoy Point, and Nantucket Beach are nothing but sandy hooks; Marthas Vine-

yard and Nantucket Islands contain half a score of such examples. Sandy Hook Peninsula, now an island and an obstruction to the navigation of Lower New York Bay, is one of the most striking examples. Find similar examples on the shores of the North and Baltic Seas.

The effects of the tide in scouring out estuaries have already been noted, but there are certain effects of tidal currents that, at first, are not obvious. Waves are capable of battering down a cliff, but they are not able to remove the material, and this, in time, lodging at the foot of the cliff, would protect it from any further assaults of the waves. But if the tidal currents remove this material, the waves have an unprotected surface upon which to work.

The bars at the mouths of rivers are nearly always the work of tidal currents, and so are many of the "banks" or shoals that obstruct straits and sounds. The North Sea contains many examples, and Lower New York Bay is so full of them that only a small part is available for deep-draught vessels.

Ocean currents undoubtedly transport an enormous amount of material. The Gulf Stream sweeps the shells of certain marine organisms from the Caribbean Sea as far north as the Carolina coast. The icebergs floated by arctic currents bring down a large amount of gravel and bowlders which are finally dropped in lower latitudes. Both the bank on which the Florida Reefs are built, and that on which the Bahamas have been formed, are thought to have been the work of marine currents. It is by no means impossible that constant deposition of matter carried by ocean currents may have resulted in extensive changes of level in various parts of the earth's surface.

QUESTIONS AND EXERCISES.—If possible, evaporate a small quantity of stream water of any kind in a beaker, or a porcelain dish,

and note the result. Repeat the experiment with rain water. What inferences can be drawn that are applicable to the second paragraph of this chapter?

Prove that ice, bulk for bulk, is lighter than water.

If possible observe the effects of waves on the shore of any convenient body of water. Note the character of the work they do, or that you find they have done. Explain how waves make beach sand.

If you are near the ocean, find the season of the year when the tides are highest.

Refer to the map, p. 199, and note the direction of the tide waves in various parts of the Atlantic Ocean. What is their general direction in the South Pacific?

Explain how ocean currents may affect navigation, either favorably or adversely.

In one of the first chapters of his narrative, Robinson Crusoe speaks of the great indraught of the Gulf of Mexico; what feature is meant?

Of several thousand sealed and registered bottles thrown into the Gulf Stream, off the Florida Coast, a number were found afterward in the Caribbean Sea, along the West Indies; from the current chart, p. 201, explain their movement.

From any available cyclopedia, or other work of reference, prepare an account of one or more of the following: the Gulf Stream, the Maelstrom, the bore of the Amazon, the tides of the Bay of Fundy, the Hell Gate, or the effects of storm-waves.

COLLATERAL READING AND REFERENCE.

PILLSBURY.—The Gulf Stream. *United States Coast Survey.*

MILL.—Realm of Nature, pp. 154–184.

SHALER.—Sea and Land, pp. 1–74, 187–222.

U. S. HYDROGRAPHIC OFFICE.—Use of Oil in Storms.

NOTES

[1] Color names are of frequent occurrence in the nomenclature of the arms of the sea. The color of sea-water is both apparent and real. The apparent hue is often due to reflection from the sky; the real color to the substances in solution. Shallow water is commonly greenish; deep water a dark blue. The water of the Gulf Stream has a peculiar blue color and is instantly distinguished from the lighter colored water on either side. The

phosphorescence of sea-water, usually observed in warm regions, is due to a microscopic organism, *Noctiluca miliaris*, that, like the common firefly, has the power of emitting light. At times the wake of a vessel seems like a track of fire.

[2] Bulk for bulk, ice is lighter than water. Solid sea-ice floats with about one-eighth of its mass above the surface. If it contains air-bubbles, however, a greater proportion is out of water.

[3] In a few instances the formation known as *anchor ice* takes place. It results from the freezing of fresh water at the bottom of an estuary into which salt water flows. The ice accumulates on the bottom until its buoyancy overcomes the force with which it adheres to the bottom; then the whole mass rises to the surface. It receives its name from the fact that it is very apt to begin forming about anchors or other metallic substances lying at the bottom. In certain cases these have been lifted from the bottom and floated. In some instances large areas of anchor-ice have become suddenly detached from the bottom, and the estuary, a few minutes previously free from ice, becomes filled with sludge. This form of ice is also called *ground-ice.*

[4] The formation of the pack is sometimes sudden and frequently violent. The crunching from side-pressure is so great that not only is the ice piled up in huge blocks, but the blocks, often weighing many tons, are shot up into the air ten or twenty feet.

[5] The difference in the form of the Greenland and the south polar icebergs is due to the character of the glaciers from which they are broken. Antarctic glaciers are derived from *sheets* of land ice; Greenland bergs, on the contrary, are derived mainly from the hummocky ice of glaciers that flow in ravines. It is commonly asserted that most of the icebergs floating down through Davis Strait come from Humboldt Glacier. As a matter of fact scarcely a single one comes from this quarter; they nearly all come from Disko Bay.

[6] A breeze of two miles an hour throws the surface of still water into ripples two or three inches broad and not far from an inch in height. The slope of the wave is rarely the same on both sides. The wind pushes the crest forward so that the front of the wave is considerably steeper than the back. Large waves as a rule result from the union of smaller ones, and this process goes on until, finally, the accumulation is the greatest mass that the breeze of the given velocity can move.

[7] Strictly speaking, it is a matter of *adhesion* rather than friction, and when the wind blows over the surface of still water the lower surface of the air actually remains in contact with the water. In a stiff gale the dragging force exerted on the surface of the water by the wind amounts to a little more than one ounce on each square yard of surface.

[8] The effect of the wind is to push their crests forward rapidly, practically flattening them.

[9] A stanch vessel *with her head to the wind* need fear but little from the waves. The latter may smash everything above deck, but the hull will ride the waves safely so long as they do not board her. Riding so that the waves strike broadside, however, is a different matter, and no vessel can accomplish it without danger of foundering. The danger from waves arises not so much from their height but from the possibility of their breaking upon and boarding the vessel. Otherwise a ship can ride waves of sixty feet as safely as those of six.

[10] In the use of oil and similar substances two results must be studied—namely, to prevent the *growth* of waves, and to prevent their breaking. In the great majority of instances, however, the problem before the sailing master is to prevent the breaking of waves. For this purpose it is found that sperm oil and oil of turpentine are the best. In use, the oil is poured into a coarse canvas sack and the latter is floated to the windward of the vessel, being held in position by any convenient outrigging. The oil oozing through the canvass spreads rapidly over the surface of the water. Instantly the waves, though they may run high, cease to break. The following from the log of the Swedish brigantine *Drott* is one of a great many similar testimonials gathered during the past few years by the United States Hydrographic Office: "I had seen upon the pilot chart that oil had been used with good effect in calming heavy seas. I started to try it and had two bags made of the capacity of two gallons each. These bags were stuffed full of oakum, and then one gallon was poured into each, half fish oil and half petroleum. A very small hole was cut in the bottom of each bag which allowed the oil to drop out freely. One of these bags was suspended from each cathead, just out of the water, and the result was simply a wonder to me, so much so that I could hardly believe my senses. No more seas were shipped and all hands turned to secure the main hatchway prop-

erly, which was impossible to do before on account of the risk of being washed overboard. The former combers were now great rollers only, not a sea breaking nearer than thirty feet from the vessel. The crew were now able to pump out the ship and clear up the decks in perfect safety. About 11 P.M. the sea broke over the starboard side and smashed in one of the boats, but this was found to be due to the loss of one of the oil bags, and as soon as another was put out and kept supplied with oil no more waves came on board."

[11] This theory of the tides is not accepted by all astronomers. *See Appendix, Table VI.*

[12] At Lady Franklin Bay, Lieutenant (now General) Greely observed that the tide came from the north.

[13] During pleasant weather the eddy of the Maelstrom is hardly noticeable during slack water, or at the time of neap tides. When the flood or the ebb of spring tides is strong, however, the current is strong, and, with a hard northwest wind, it is a dangerous locality.

[14] According to Herschel and Carpenter the winds themselves pile up the waters in equatorial latitudes, thereby bringing about a condition of inequilibrium. Lieutenant Maury held that the difference in specific gravity between the saltier waters of equatorial and the fresher waters of polar regions is competent to account for ocean currents. That each is an important factor cannot be denied.

[15] Owing to the turning of the earth on its axis, a point on the equator travels 25,000 miles in twenty-four hours—a speed of about 1,000 miles an hour. In latitude 60° it is only half as much. Consequently water flowing from latitude 60° toward the equator, every point of which has a greater velocity, has a tendency to lag behind.

[16] The velocity varies not only with the season, but also with the age and the passage of the moon—that is, the variations are yearly, monthly, and daily. The velocity is greatest during summer and least in winter. The position of the axis of the stream, or line of swiftest flow, changes also with the season. An adverse wind will retard; a favorable wind will increase its velocity. A quartering wind or one blowing athwart is apt to push some of the surface water out of the track of the stream, at the same time pushing colder water into it. The fact that Gulf Stream water

is occasionally pushed against the coast has more than once given rise to the statement that its position is subject to change.

[17] Glaciers and glacial action have also had much to do with the shaping of surface features of these coasts. The coasts of Ireland, Norway, Alaska, and Chile much resemble that of Maine. Their general outline, however, is due to submergence; with the lowering of the level of the land, the waters cover the valleys.

[18] During the reign of Henry VIII. the church of Reculver stood at the distance of a mile from the shore, but the sea now laves its foundation stones. The famous Goodwin Sands, a shoal about twenty square miles in extent, southeast of Kent, was formerly a part of the mainland. In the twelfth century, during a severe storm, this area was washed away by the sea, and has been covered with water ever since. The channels through this shoal shift with every storm.

CHAPTER XII

THE ATMOSPHERE AND ITS PROPERTIES: WINDS

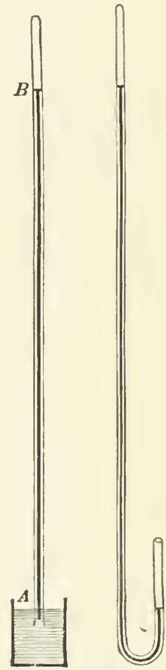
THE atmosphere, or air, is the gaseous substance that forms the outer envelope of the earth. It rests on the land and the water, and probably penetrates both to a considerable distance. Being a part of the earth, the atmosphere partakes of all the general motions of the latter, but it has also certain movements of its own, and these are very closely connected with life and its environment.

The air is not a simple, or *elementary* substance; as noted on p. 22, it is a mixture of several elements. The chief constituents, nitrogen and oxygen, have the proportion of about four parts of the former to one of the latter, and the proportion does not change materially. The remaining constituents, water vapor, carbon dioxide, and floating matter vary greatly. The vapor of water rarely exceeds one part in one hundred of air. It is nevertheless a most important constituent, for it is in this form that the water is borne from the sea and shed upon the land. The floating particles of smoke, dust, and other matter are also essential, for they aid materially in condensing the water vapor.

The air is highly elastic. Stop the nipple of a bicycle pump and push the piston quickly; note what occurs. Pressure, therefore, decreases the volume, making the air *denser*. When the pressure is relieved, the air again expands and is less dense or *rarefied*.[1] Air next the ground is denser than that above, because of the pressure

or weight of that overlaying it. The density decreases with the distance above the sea; at an altitude of two miles the density is only two-thirds that at sea-level. At sea-level a cubic foot of air weighs a little more than one Troy ounce.

The force with which the air presses upon a given surface is called its *tension;* and, practically, the tension is a form of expressing its pressure[2] on the rock envelope. At sea-level, the column of air rests upon the surface with a pressure of about fifteen pounds on every square inch, or a little more than a ton on each square foot of surface. The tension varies slightly in different latitudes, being a little greater near the tropics than elsewhere.



THE BAROMETER.

It is most convenient to estimate the tension of the air by observing the height of a column of mercury, or quicksilver, that will just balance it. The instrument used for this purpose is called a *barometer.* It consists of a glass tube closed at one end, and filled with mercury; the open end is placed in a small cup filled with mercury. The pressure of the air on the surface of the mercury in the cup keeps the column in the tube in place. If the column in the tube rises it signifies that the pressure of air overhead is increasing; if it falls, the pressure is decreasing. The weight of the mercury in the tube is just equal to that of a column of air, having an equal base, and the two balance each other.

The atmosphere is warmed partly by the direct rays of the sun and partly by the heat radiated from the earth.

It is also heated by compression and cooled by expansion. When a volume of air is compressed, it becomes greatly heated. Thus, air that descends from higher to lower levels, becomes heated because it moves into a region where the density and tension are greater. In the same way, a volume of rising air expands and is cooled, because it goes into a region where the tension and density are less. Heat causes the air to expand and, bulk for bulk, warm air is therefore lighter than cold air.[3] If a volume of air is warmed from freezing temperature to that of intense summer heat its volume is increased nearly one-fifth.

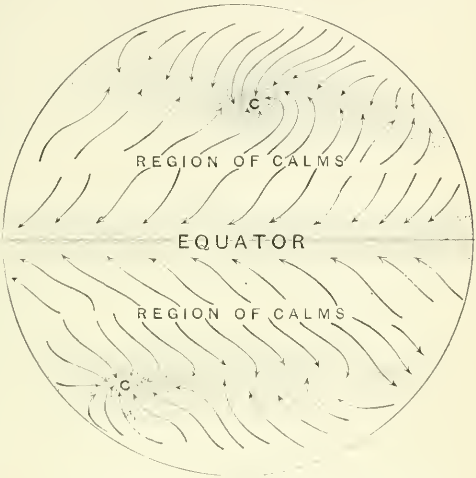
The temperature of the air varies both with latitude and with altitude. In equatorial latitudes the mean temperature of the air over the sea is not far from 32° (90° F.); in polar regions it ranges much below 0° (32° F.). With respect to altitude there is a fall of temperature at the rate of about one degree for every three hundred feet of ascent. The effect is very noticeable in the equatorial Andes. At the base of the mountains the heat is intense; at an altitude of ten thousand feet the air is mild and pleasant; at seventeen thousand feet one lives in a region of perpetual snow.

Movements of the Atmosphere.—Like the waters of the sea, the air is everywhere in motion. The movements are both general and local. The attraction of the sun and the moon undoubtedly causes atmospheric tides something like the tides of the sea. Their effects, however, are very slight, and practically nothing is known about them.

Sensible movements of the air are called *winds*, and they are caused by changes of temperature. When the air at some locality or other is heated to a temperature higher than that surrounding, it expands and, becoming lighter, bulk for bulk, it is pushed upward by the heavier

air that flows in. In this way winds originate. Such movements of the air are everywhere taking place, and it is evident that they are examples of the force of gravity.

Equatorial and polar regions are not equally heated. The former receives the almost vertical rays of the sun; the latter only oblique rays. The air in low latitudes, therefore, is warmed and pushed upwards by the inflow of colder air. This process results in two great movements, namely—*a surface flow toward the equator, and upper currents from the equatorial toward polar regions.*



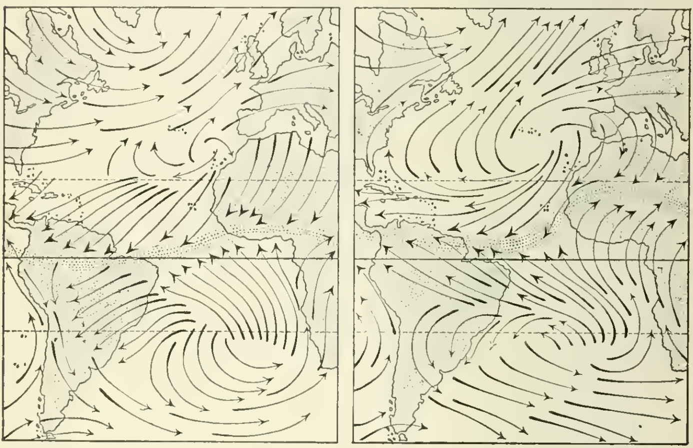
GENERAL MOVEMENTS OF THE ATMOSPHERE.

But the colder air comes from the regions where the speed of the earth's rotation is comparatively slow, and enters latitudes where it is much greater; and not being able to acquire this speed at once it lags behind, producing a current to the westward. The rising current moves into a region in which the speed of rotation is not so great, and therefore moves eastward, as well as toward the north.

Winds are usually named according to the direction from which they come. But in the two great movements described the easterly and the westerly components are much more noticeable than the polar and equatorial move-

ments. For this reason it is customary to recognize three great belts of winds—a belt of equatorial or *easterly*, between two zones of extra-tropical or westerly winds. These general movements are very strongly marked in the oceans, but they are greatly modified by the continents; in inland mountainous regions they might escape notice except through long-continued observations; in the great lowland plains they are more regular.

Trade Winds.—The surface winds that flow into tropical regions to take the place of the warm air that is



January. *July.*

PREVAILING WINDS OF THE ATLANTIC.

pushed upward, form the well-known Trade Winds. What is their direction in the northern half of the belt? in the southern half? Toward the centre of the belt they are practically strong, steady easterly winds.

The zone of Trade Winds is about fifty degrees in width. Its position is not stationary; it swings back and forth, north and south, as the seasons change. In the Atlantic Ocean the shifting of the belt is not far from eight or ten

degrees; in the Pacific it is slightly greater. The belt reaches its northern limit in early autumn; its southern limit in early spring. The winds are regular and constant the year round, and their velocity is not far from twelve or fifteen miles an hour.

Formerly, when most of the ocean commerce depended on sailing vessels, these winds were of great importance—hence their name. A vessel entering the Trade Wind belt could rely on steady winds with but little interruption from cyclones.

Along the line where the northerly and the southerly components of the Trade Winds meet, there is a narrow belt which is characterized by an absence of steady winds. This belt is the updraught of heated air and is called the *Equatorial Calms*, or *Doldrums*. This calm belt is scarcely more than two or three hundred miles in breadth. Sometimes vessels were becalmed several weeks in crossing it. The wind comes only in fits and puffs, or with an occasional thunderstorm of great violence.

Prevailing Westerlies.—The air that flows from equatorial regions as an upper current,[4] in temperate latitudes sinks to the surface and becomes a belt of westerly winds, now generally called the *Prevailing Westerlies;*[5] what is their direction in the Northern Hemisphere? in the Southern Hemisphere? Like the Trade Winds both belts move northward and southward with the changes of the seasons.

In the Northern Hemisphere the Prevailing Westerlies are neither so strong nor so steady as the Trade Winds, and in higher latitudes they often give way to winds of northerly origin. On the coast of the Gulf of Mexico the Prevailing Westerlies, in the summer season, are reinforced by Trade Winds which are deflected by the highlands of Mexico. The resulting winds sweep up the Mississippi

Valley and thence turn across the Atlantic, carrying with them a great deal of the moisture that supplies the Eastern United States with rain.

In the Southern Hemisphere, the Prevailing Westerlies are best known as the *Roaring Forties*. They cover a very broad stretch of sea, and they furnish an excellent illustration of the theoretical movement of the constant winds. When the trade route between Europe and the East Indies lay around the Cape of Good Hope, the Roaring Forties were a very important factor, as the sailing master could depend on a twenty or thirty knot breeze the year round. It was then a common practice for vessels bound for Australia or New Zealand to continue the route eastward and return by way of Cape Horn. Trace this route on a globe.

The descent of the upper currents to the surface, which is the origin of the Prevailing Westerlies, is marked by calm belts—the Calms of Cancer, and the Calms of Capricorn. Like the zones of constant winds the calm belts also shift north and south with the season. They are interrupted by the continents and are scarcely to be noticed within a hundred miles of their shores. The Calms of Cancer are the well-known "Horse Latitudes."[6] The Calms of Capricorn are the wider and more continuous of the two calm belts.

Monsoons.—Along many coasts having a southerly or a southwesterly exposure the summer winds have a direction nearly opposite those of the winter season; that is, about half the year they blow *from* the sea; the remaining half *toward* the sea. These winds are called *monsoons*.[7] Two causes operate to give these winds their peculiar character—in some instances singly; in others together.

In the first place, any great body of land is apt to become much warmer than the sea in summer and colder in

PREVAILING WINDS

winter. As a result, during summer there is an updraught of warm air pushed upward by the inflow of sea air. In winter the conditions are reversed; cold air flows from the land to the sea. In other instances, a region may be so situated that it is in the southeast Trade Winds at one part of the year, and in the northeast part the remainder. The monsoons of the Mexican coast are probably due to this cause.

The most remarkable monsoons, however, are those of the Indian coast.[8] From April to October the southerly half of the belt of Trade Winds reaches far inland, pouring a deluge of rain upon the land. During the rest of the year, on the contrary, the southerly part of the belt has reached southward, and the northerly half extends considerably beyond the coast, parching the land and withering vegetation. The tremendous updraught of warm air aids materially in giving strength to these winds. The "breaking" or change of the monsoon is usually attended by a number of terrific storms.

Along the Gulf coast of the United States the deflected Trade Winds of the summer season, noted on p. 219, that flow *up* the Mississippi Valley are replaced by Prevailing Westerlies that are turned *down* the valley. These winds may be regarded as monsoons, but they are neither so regular nor so strong as the Indian monsoons.

Day and Night Breezes.—The difference between the temperature of day and night is sufficiently great to result in strongly marked local winds. Thus, along the coasts, especially warm regions, the updraught of the land causes a stiff on-shore wind during the day, while at night the air over the land, being more quickly chilled, flows down the slopes toward the sea.[9] Thus there results a sort of daily monsoon, or day and night local wind. Coast fishermen frequently take advantage of such winds; they go

out in the morning with an off-shore, and return at night with an on-shore breeze.

Similarly, in mountainous countries the air upon the higher slopes is commonly heated and cooled more rapidly than in the valleys. As a result there is often a strong wind blowing *up* the valley by day, and flowing *downward* at night. *Mountain valley winds* of this character are very common in almost every rugged country. Which is the better indication of the general direction of the wind—that noted at the ground, or the movement of the clouds?

Local and Variable Winds.—There are many winds occurring at irregular intervals that are confined each to a particular locality. In most instances these winds are confined to desert regions and arid lands, or else they result from the proximity of the latter. Almost always they are very "dry" winds.

Thus, the *Northers* of Texas and Mexico are cold winter winds of several days' duration that blow from the highlands of the Plateau region. The *Chinook* and *Santa Ana* winds of the western highlands of the United States are descending, and therefore warm winds blowing from arid regions upon fertile lands. In southern Europe they are called *Foehn* winds.[10] The *Pamperos* are similar winds flowing from the cold slopes of the Andes over the arid pampas of Argentina. The *Puñas* of the Peruvian tablelands are of the same nature.

In the vicinity of the African desert are the famous *Mistral* and the *Etesian* winds, both blowing from the snow-clad Alpine ranges toward the desert, while the *Sirocco*, like the Chinook, is a hot wind that in summer blows from the desert. The *Harmattan* is a warm winter wind, blowing from the desert to the Guinea coast. Aside from these there are several winds peculiar to desert regions. Chief among them is the *Simoon*, a fierce blast of

hot air and rock waste, that neither man nor beast can face. It is common both in the Old World and the American deserts. A milder form of this wind along the lower Nile valley is called the *Khamsin.* Classify these winds as either hot blasts *from* the desert, or colds winds blowing into it.

The most interesting of all desert winds, however, are the sand whirls. These occur in the morning when the air is still—*never* when wind is blowing. Under a hot sun the air next the earth becomes considerably heated, having a high temperature. Above the ground the air is cooler at the rate of one degree F. for every three hundred feet. Thus there is formed the very unstable condition of a layer of heavy, cold air on a surface stratum that is much lighter. Such a condition cannot last long, and sooner or later some slight disturbance or other starts a slender column of air upward.

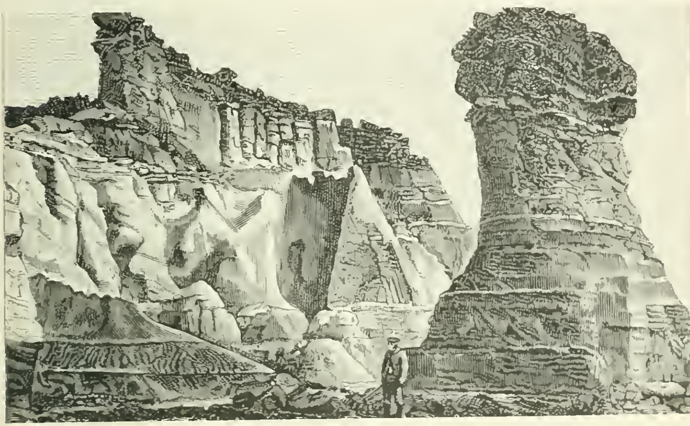
Immediately the stratum of cold air begins to settle, and, as it descends, it forces the warm air upward through the self-made passage. The ascending column begins to whirl, and soon its motion is rapid enough to carry with it a cloud of dust and fine rock waste.

As a rule these whirls begin when the sun is two or three hours high, and continue until the wind begins to blow. The latter, by mixing the warm air with the cold, prevents their formation until a calm again begins. Occasionally such whirls develop into very vigorous "sand spouts."

Physiographic Effects of Winds.—As an agent in wearing away the surface of the land, the wind acts in different ways. It may alter the chemical composition of the rock with which it comes in contact. It may carry minute particles that cut away softer material. It may transport material from one place to another. The chemical action

of air is due mainly to the water and carbon dioxide which it contains. It is manifested in the gradual crumbling of many rocks, when the latter are exposed to the air. The rocks most affected are certain iron ores and granite rocks. Dry air may affect rocks by chemically withdrawing the moisture they contain; moist air may affect other kinds by chemically imparting water to them. In either case the rock sooner or later crumbles.

The impact of minute particles carried by the wind is especially noticeable in the western highlands. In regions



SAND-BEATEN ROCKS

where sand winds are prevalent the surfaces of the hardest rocks are worn, channelled, and polished from this cause. Many of the "needles" or rock spires of this region have been sculptured into fantastic forms by *æolian* or wind-blown rock waste.[11]

The transporting power of the wind is confined chiefly to sea-shores and regions unprotected by vegetation. Why? The wave-formed islands and barrier-beaches of

the Atlantic and Gulf coast have foundations of sea sediments, but the above-water part consists of wind-blown material. The sand-dunes of sea and lake shores are excellent illustrations, and in regions swept by monsoons the dunes travel seaward during one season and landward the other. A wave of sand about a mile long and seventy feet high at one time inundated a part of Cape Henlopen.[12]

Between the silt brought down by the Colorado River, and the fierce winds of that region, the Gulf of California

DUNES OF SAND

has been cut in twain, and most of the severed portion filled with rock waste to a height now considerably above sea-level; indeed, all through this region dunes are constantly forming, shifting, and re-forming. In western Nebraska, where the rainfall is not sufficient to grow protective vegetation, dunes are common.

Very notable examples of the transporting power of wind occur in China. In the basin of the Hoang River there are æolian deposits covering many thousand square miles to a depth of several hundred feet. These deposits,

called *loess*—from a German word meaning "loose"—are thought to come from the desert region to the westward. In many places the rivers have cut their channels through the loess, and the latter not only colors the water of the river, but imparts a yellow tint to the sea into which it flows.

Æolian deposits have filled most of the valleys of the Basin Region of the western highlands. The ranges stand out in bold relief from an ocean of level rock waste. Many of the valleys of the Rocky Mountains have been filled and levelled in the same manner.

QUESTIONS AND EXERCISES.—Devise or describe an experiment to show that air has weight; show that it is elastic; show that heating a volume of air causes it to expand; using a bicycle pump, show that compressing air warms it.

What is the prevailing direction of the wind in the locality in which you live? Consult the records of the nearest weather station and compare the number of days of westerly winds with the number in which the wind is from other directions.

The tropical calm belts are regions of descending air-currents; is the air apt to be chilled or warmed by this movement?

Read Stedman's poem, "The Simoon," and compare it with the description in any standard cyclopedia.

Why are northerly winds apt to be cold?

Explain the manner in which street whirlwinds are formed

Note any instance of the physiographic effects of winds in the locality with which you are best acquainted; prepare a description of it.

In what way do the general winds affect the temperature of the earth?

Note any examples in which winds accomplish work that has an economic value

COLLATERAL READING AND REFERENCE.

U. S. Coast Survey.—Atlantic Coast Pilot Chart, for March and September, or February and August—any year.

Le Conte.—Elements of Geology, pp. 1–8.

NOTES

[1] At a height of fifteen thousand feet the air is so rare that breathing is labored and the pulsations of the heart are very rapid. Climbing becomes difficult and any form of exertion is very wearying. Water boils at about 85° (185° F.), a temperature so low that it is difficult to cook vegetables by boiling.

[2] Approximately the pressure is one-half a pound for every inch in the height of the column of mercury. At the level of the sea, the height of the barometer varies usually between 29 and 30.4 inches.

[3] It is well to bear in mind that the common expression, "hot air rises, because it is lighter," is not strictly correct. The hot air does not rise; it is pushed upwards and floated on the surface of the heavier air.

[4] The height to which the updraught rises before it turns toward the pole is not known, except in two or three instances. On the Island of Hawaii, the Trade Winds reach an altitude of about twelve thousand feet. Above this elevation the winds have almost an opposite direction; they are the winds that, a few degrees farther north, descend to become the Prevailing Westerlies.

[5] The Prevailing Westerlies are also called *return-trades, anti-trades*, and *counter-trades.* The name here used is now commonly employed in meteorology.

[6] Many years ago, when most of the foreign carriage was effected by sailing vessels, there was a brisk trade in horses between the ports of the New England States and the West Indies, nearly all the horses used in the latter country being obtained from New England. Frequently the vessels were becalmed in this belt, and it became necessary to throw overboard half the number of horses, in order to save the remaining animals.

[7] The name is derived from a Malay word, meaning "season."

[8] On account of its inland position, Central Asia is marked by great extremes of temperature. During summer its vast deserts are almost like a furnace, and the updraught of heated air is so enormous that it causes atmospheric disturbances two thousand miles away. In winter the dry air is chilled many degrees below

that of the warm sea-air, and, being correspondingly heavier, flows outward toward the ocean. No other body of land possesses the qualities requisite to produce monsoons that compare with those of Asia.

[9] A similar movement of air is noticeable in many large caves —especially those that have openings at different levels. In the daytime air in the cave is usually colder than that outside, while at night it is warmer. As a result, at night there is a strong in-draught of colder air at the lower entrance, and an up-draught at the higher opening. In the daytime these movements are reversed.

[10] These three names are applied to winds that have certain principles in common. Warm, moist air is pushed up the side of a mountain-range ; being cooled either by its own expansion, or by contact with the colder mountain top, its moisture is condensed ; the air then descending on the other (or possibly the same) side warms very rapidly by its own compression. The effect is very marked ; snow disappears very rapidly—hence the popular name "snow-eaters." The descending air is not only warm, but it is so dry that in summer it withers vegetation. The Chinook wind gets its name from a locality in Oregon, whence it seemed to come, but the name is now applied to warm winds that flow from the Rocky Mountains out on the plains to the East. Following a blizzard, it quickly melts the snow that covers the scanty feed of the cattle herds. The Santa Ana is a hot wind common in southern California and Mexico.

[11] Some years ago the author left an octagonal steel drill in an upright position exposed to the full sweep of a desert wind. Six months afterward its angles had been almost obliterated by the impact of rock waste. The telegraph poles in these regions are frequently cut in two by the wind-blown rock waste.

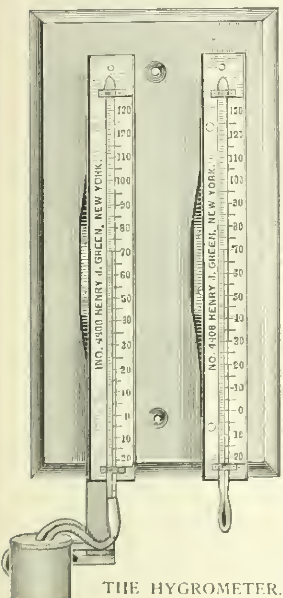
[12] It is likely that a fire, which in 1828 burned off the vegetation protecting the ridge, was responsible for starting this dune on its travels. In 1845, General Joseph E. Johnston, then a government engineer, noticed that north winds were very actively at work in picking up sand from the seaward face of the dune and carrying it over the crest to the landward side. Little by little the wave of sand overwhelmed a strip of pine barrens and filled a salt marsh beyond. Then it advanced upon a heavy growth of timber and, in time, covered all but the tallest trees, killing them

as effectually as though they had been swept by fire. As the years passed by the wave steadily advanced, and the wind began to uncover the buried surface in the rear. First the strip of pine barrens re-appeared, and then the salt marsh was cleaned out and promptly reclaimed by the tide. Even the pine barrens began to show signs of life and a growth of young trees sprang up. Within the past few years the advancing sand has begun to uncover the forest, and a border of dead trees now flanks the rear slope. Near the eastern end of the dune is Cape Henlopen light-house. A straggling ridge of the wave entered the yard, covered up the oil-house and the garden, and then took possession of the keeper's cottage. The Government acknowledged its inability to cope with the dune by erecting a new cottage on the other side of the tower.

CHAPTER XIII

THE MOISTURE OF THE ATMOSPHERE. SEASONAL AND PERIODICAL DISTRIBUTION OF RAINFALL

THE vapor of water mingled with the atmosphere, in a way, may be considered a part of it;[1] but, if all the other constituents were absent, the water vapor would exist as an atmosphere in itself, and its movements would be the same practically as those of the winds. But while the proportion of oxygen and nitrogen of the atmosphere do not perceptibly vary, that of water vapor is subject to rapid changes. The amount present depends on one thing only—temperature. With a high temperature there may be a great deal of vapor mingled with the air; with a low temperature there can be but little.



THE HYGROMETER.

Changes in humidity are usually apparent to the sense of feeling, and one readily learns the difference between moist and dry air.[2] In many instances they may be forecast by observing the clouds. If the latter form rapidly, or if small patches of cloud increase in size, the humidity is increasing. On the contrary, if the cloud area is becoming smaller, it is highly probable that the humidity is decreasing.

The amount of moisture is determined in various ways Most commonly the *hygrometer*, an instrument employed to measure the amount of moisture, consists of two thermometers, the bulb of one being covered with a single thickness of wet cloth. If the air be dry, the water that saturates the cloth evaporates rapidly and chills the bulb, so that the reading of the thermometer is several degrees lower. If the air is moist, on the other hand, very little evaporates, and the difference in the reading of the thermometers is very slight. From the difference in the readings of the two thermometers the amount of moisture may be calculated.

Dew Point.—Table VII., Appendix, shows the amount of water vapor there may be in the air at various temperatures.[2] With the thermometer at 66° F., for instance, there may be seven grains in each cubic foot of atmosphere. There might be less, but there can be no more; if more be added it would immediately *condense*—that is, change to rain or snow. From this table find whether or not there may be vapor in the air when the temperature is below freezing-point of water. Compare the amount at 70° F. and 90° F. Learn the temperature at the time of recitation, and find the amount of moisture there may be. What is the general law shown in this table, so far as temperature and the percentage of moisture are concerned?

When all the vapor that can exist at a particular temperature is present, the air is said to be *saturated* or at the *dew-point*.[3] This condition is unusual, however, except when rain is falling; generally the amount present is considerably less than that required for saturation. From the amount present one may easily compute the *relative humidity*; thus, if half the quantity required to saturate the air is present, the relative humidity is fifty per cent. What is meant when the relative humidity is eighty per cent.? If the amount is near the dew-point, the air is moist; if

the relative humidity is low, it is dry. Air that is moist at a given temperature may feel very dry at one that is higher, even though no more moisture is present.

Latent Heat of Evaporation.—Water is changed to vapor by heat. When water boils it reaches the temperature at which it begins to change rapidly to steam. No matter how fierce the heat may be, the water (unless it is confined under pressure) gets no hotter, and the steam given off has a temperature no higher than that of the boiling water.

All this heat is absorbed in the work of changing the water to steam, and it is called the *latent heat of steam*. It has not been lost, however; it is merely stored-up energy. It is retained just so long as the water remains in the form of vapor; it is given out the moment the vapor is condensed, or changes to a liquid.

This property of water is one of the greatest importance, for, as will be shown, it is a chief factor in the atmospheric disturbances called storms. The amount of heat thus rendered latent is very great. For every pound of water converted to steam, as much heat is required as would raise nearly half a ton of water one degree F.

Dew.—Dew is the moisture that gathers on the ground after sundown. Both the air and the ground lose a part of their heat. The latter cools more rapidly, however, and finally the layer of air next the ground is chilled below the dew-point. When this occurs, the excess of vapor in the form of minute drops gathers on the grass and on other objects near the ground. The moisture that gathers on the outside of a glass of iced water is an example.

Dew does not always form at night, and for this there are several reasons. A stiff breeze may keep the air thoroughly mixed, and thereby prevent any part of it from being chilled to the dew-point. The air may contain

so little vapor that a fall of fifteen or twenty degrees does not bring the temperature to the dew-point.[4] A cloudy sky, especially if the clouds hang low, prevents the radiation of heat, and the formation of dew.[5]

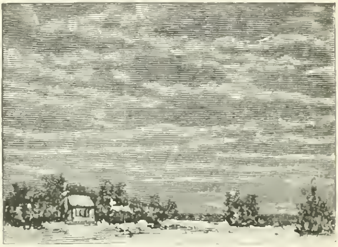
The amount of moisture in the air varies much. In tropical regions, especially those near the sea, the amount is proportionately very great. Sometimes it is so near the point of saturation that the air becomes hazy. In such regions dew forms copiously. In temperate latitudes the amount is much less than in tropical regions.

In the California and Sound valleys, where there are no summer rains, the fall of dew in early summer is excessive, and to a great extent the grain crop is dependent upon it. The same phenomenon occurs in most mountain valleys.

If the temperature of the dew-point be lower than 0° (32° F.), the moisture may pass immediately into the crystalline form, *frost*. Sometimes the minute frost crystals form in the air, but usually they accumulate on the grass, the leaves, and other objects near the ground. Sometimes the frost is simply frozen dew. Except at considerable altitudes frost does not occur in tropical regions. In temperate latitudes it may occur at any time between late fall and spring. Late spring frosts are apt to occur after fruit-trees have budded, and they are therefore commonly known as *killing frosts*. The cold wave that follows a spring storm is very apt to lower the temperature to the freezing-point, and if the air be moist, a killing frost commonly occurs. Fortunately its occurrence usually can be predicted.

Clouds.—When the temperature falls so low that a part of the vapor is condensed, the latter does not at first gather into large drops; on the contrary, the drops are so minute that they float in the air. This floating mist of the air is called *fog* or *cloud*, according as it is at the surface of the earth or high in the air.

Nearly always the air is filled with dust-motes and other floating matter, and much of the condensing vapor gathers on these. Not only do the dust-motes form a lodgement for the condensing vapor, but they cool more rapidly than the air, and thereby quicken the process of condensation. Floating matter in the air thus becomes an active agent in cloud formation. The cooling of the air below the dew-point, however, is the essential, and this may occur in several ways. Thus, when a mass of air is pushed upward, not only is it chilled by going into a cooler position, but it is also cooled by its own expansion. It is probable that the greater amount of cloud is formed in this manner. Thus, in equatorial regions, where there is a constant up-draught of warm, moist air, there is a perpetual cloud-belt.



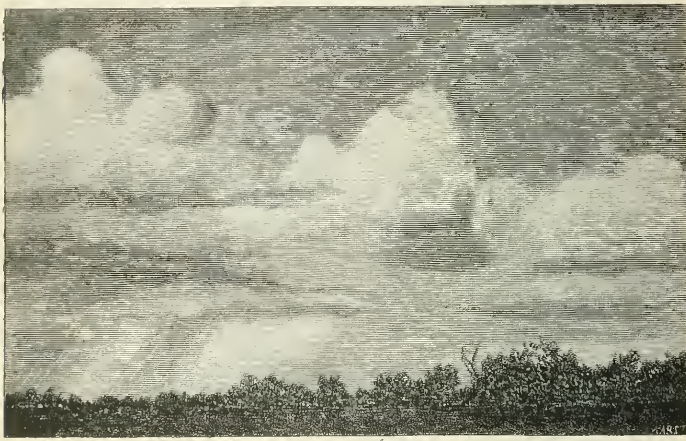
CIRRO-STRATUS CLOUDS

The intrusion of warm winds into cold regions, or of cold winds into warm regions, is also a common cause of fog and cloud. If the intruding wind is at the surface of the earth fog results; if at a considerable elevation cloud is formed. The fogs and cloud banks so common off the coast of Newfoundland are formed in this way.

Whenever a warm sea-wind blows against a high mountain-slope, a part of the air is driven up the slope, and, some of its moisture being condensed, cloud is formed. Almost always high mountain-crests near the ocean are shrouded in clouds, and not infrequently a cloud banner streams from the leeward side of a high peak.[6]

Clouds usually take characteristic forms, and these are governed mainly by the presence or absence of wind, or by

their height. *Cirrus* clouds are light and feathery in appearance and commonly white in color. These clouds take various forms. When they are flaky or fleecy they are the "mackerel" clouds heralded by sailors as forecasters of fine weather; but cirrus "streamers" are frequently found as an advance indication of an approaching cyclone. Often the patches of cirrus cloud are ranged in parallel strips; and occasionally they radiate like the spokes of a wheel.



CUMULUS CLOUDS

Commonly their altitude is between five and ten miles. On account of their great height it is obvious that they consist of minute ice crystals. Cirri may form above another cloud, the two being apparently related, but they never form under other clouds.

Cumulus clouds are the day clouds of summer weather. They appear like great, rounded domes resting on a horizontal base. A gently warmed current of air rises until, being chilled both by expansion and great altitude, condensation begins. The process continues until a dense

mass of cloud is formed. This form is the almost universal cloud of tropical regions. It is abundant in warm temperate climates, but rare in cold latitudes. It does not form at night nor in cold weather, for the simple reason that the up-draught of warm air is too feeble, and there is not enough vapor present to form clouds of sensible dimensions. Ordinarily, cumulus clouds have no especial significance as weather forecasters. They indicate nothing more than the presence of moisture, and, as a rule, their size shows whether there is considerable vapor or only a little. If, however, a mass of cloud loses its flat base, becoming ragged or festooned at the lower side, it usually portends high winds and local showers.

Stratus clouds are so called because they are flat layers of nearly uniform thickness. Normally they are the lowest of all clouds, and probably contain the greatest amount of foreign matter. These clouds are commonly observed at morning and evening, and stillness of air is essential to their formation.

STRATUS CLOUDS

The *Nimbus* is the shapeless rain-cloud that hovers near the surface of the earth. The upper part consists of light fog or mist; the lower, of falling drops. Usually it seems to form in clear air, and it gathers when the temperature reaches the dew point.

Clouds are moved hither and thither by the wind, but the matter composing the cloud is usually in motion even when the air is still. A casual inspection of any summer cloud shows that it is constantly moving within itself. Practically, cloud is floating moisture, but in reality the minute drops are always slowly falling. The droplet falls

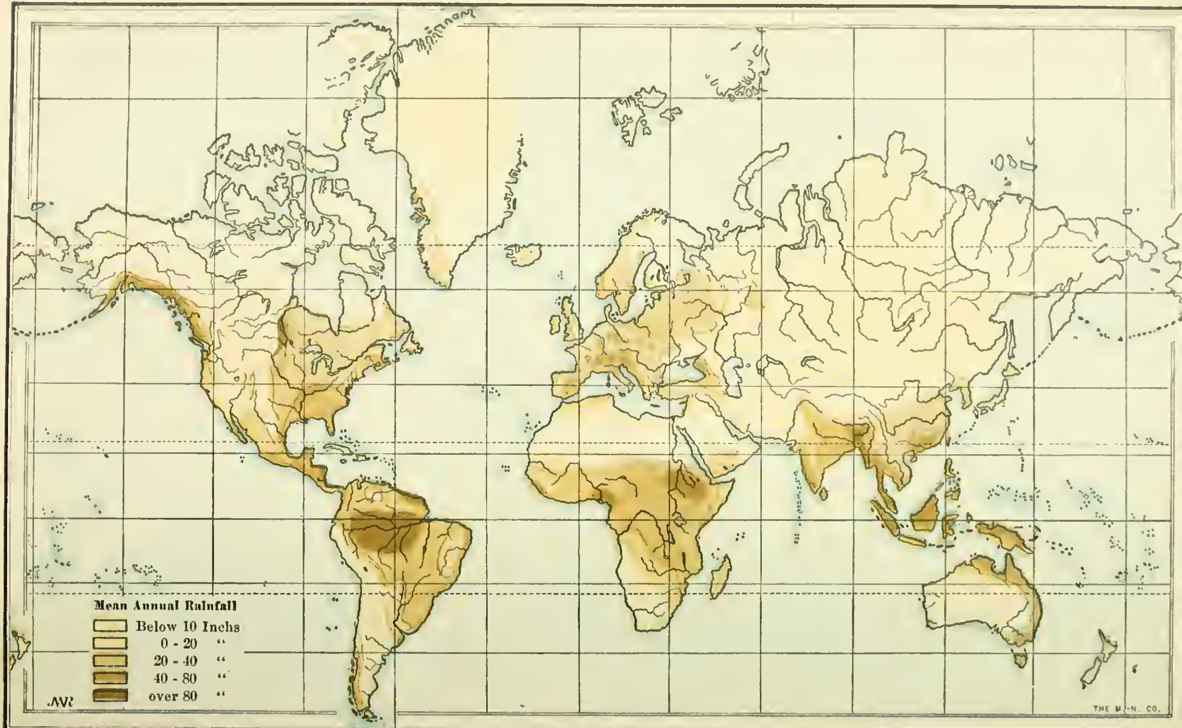
until it reaches a region of greater warmth; then it is changed to vapor, and the latter at once ascends until it is again condensed—the process being constantly repeated.

Rain.—The difference between rain and cloud consists very largely in the size of drops, but there is also a difference in their physical condition. The drops of cloud matter, or "water dust," are minute, and practically they float in the air; those of rain are each many thousand times as large, and fall quickly to the ground. The causes that operate to produce fog and cloud, however, also produce rain—namely, the cooling of water vapor below the dew-point.

The vapor precipitated as rain may pass through the cloud stage, it is true; but the latter is one of short duration, and, as a rule, when condensation begins, it proceeds very rapidly. Rain is rarely associated with fair-weather clouds, and, excepting local showers, is not derived from them. In almost every instance general rains are derived from warm ocean winds that, blowing inland, are chilled.

In general, more rain falls in tropical regions than elsewhere: does the map confirm this statement? The equatorial cloud-ring is also a rain-belt, and under it precipitation is almost continuous. The amount of rain falling in the torrid zone is sufficient to cover it to a depth probably of more than one hundred inches. In the temperate zone it is a little more than one-third, and in polar regions about one-eighth as much.

Rainfall is not uniform for all places in the same latitude.[9] On slopes that face ocean winds it is greatest, while in regions shut off from the sea by high ranges it is little or nothing. For example, on the southern slope of the Himalayas the precipitation varies from two hundred to six hundred inches; on the north side it is less than ten. On the western slope of the Sierra Nevada and Cascade



MEAN ANNUAL RAINFALL

Ranges it is ten times as great as on the eastern. Explain why the difference exists.

As a rule, precipitation is greatest at the coast and decreases toward the interior.[12] On the Atlantic coast of the United States it is nowhere less than forty inches; west of the one hundredth meridian it is less than fifteen. On the northern shores of South America it is over one hundred inches; a few hundred miles inland it is about one-quarter as much. In the uplands of the eastern slope of the Andes it again increases; why?

Not only does the amount of rainfall vary in different localities, for the reasons noted, but there is also much difference in the *time* of its distribution. In some localities it comes in the form of occasional showers; in others long periods of rain and drought alternate at given intervals[11]—that is, the rainfall is *periodical* and *seasonal*.

An examination of the wind chart, p. 221, will help to explain this fact. The slopes of the continents that face ocean winds, as a rule, have periodical rains. Thus, the western coast of North America faces the Prevailing Westerlies of the Pacific Ocean. In summer these winds are blowing into a region that is warmer, and therefore but little rain falls. In winter, on the other hand, the temperature of the land is much lower, and therefore rain may be of daily occurrence.

On the Mexican coast, where, on account of low latitude, the climate is almost always mild, but little rain falls. Along the coast of the United States it varies from ten or twelve inches at San Diego to sixty or seventy at Puget Sound; while at Sitka, Alaska, it is about one hundred inches. How will the difference in latitude explain this? In what part of the Pacific Coast of South America are the conditions similar? On the Atlantic coast of Europe the conditions are much the same; most of the precipita-

tion occurs during the winter months, but on account of high latitude a considerable rain falls in summer.

In tropical regions, where the winds have an easterly origin, the easterly slopes receive the heaviest fall of rain. In these regions, however, the rainfall follows the passage of the equatorial cloud-belt back and forth. This belt is comparatively narrow — scarcely five hundred miles in breadth. During the spring months of the Northern Hemisphere it moves northward with the sun, deluging the land over which it passes with almost continuous rain. After reaching its northern limit it turns southward, repassing over the same belt. In the American continent the cloud-belt does not pass far south of the equator; in Africa it reaches much farther south.

A moment's study will show that at each tropic, or limit of the cloud-belt, there will be one rainy and one dry season, while at intervening latitudes there may be two. Which of these conditions applies to Cuba? to the Central American states? to the Caribbean coast of South America?

Regions swept by monsoons usually have periodical rains also. The reason is obvious: during one part of the year the winds blow from the land; the remaining time from the sea. The rains of the Indian coast of Asia are an excellent example. During the winter months of the northern hemisphere the prevailing winds are land winds; but with the bursting of the April monsoon the season of heavy rain begins and the parched land is quickly covered with verdure.

A large part of the land surface of the earth is watered, not by seasonal and periodical rains, but by the precipitation that comes with the irregular movements of the atmosphere known as *storms*. These regions as a rule are either far inland, or else high mountain ranges shut them off from the reach of ocean winds.

That part of the United States east of the Rocky Mountains is an example. The ranges of the great highlands precipitate practically all the moisture brought from the Pacific, and therefore there are no periodical rains. Moisture gathers from the Gulf and also from the ocean, but for the greater part it is not precipitated until the cyclonic movement, which constitutes the storm, takes place. These disturbances occur so frequently, and there are so many of them, that almost every part of the region receives a plentiful supply of moisture. Similar conditions exist in parts of Eurasia and Africa.

Effects of Altitude.—As a rule, more rain falls at sea-level than at higher altitudes: very little falls above the height of ten or twelve thousand feet. On mountain-slopes, however, the greatest precipitation takes place below three thousand and five thousand feet. The reason is two-fold. In moderately warm regions rain clouds commonly do not reach much above this altitude; moreover at this height the ground may be cold enough to condense moisture when it is too warm to do so at a lower level. This fact is often observed in desert regions.

Rainless Regions.—There are two principal causes for the existence of rainless regions. There may be a barrier of high mountains that shut off rain-bearing winds; or, vapor may pass into a warmer region where it cannot be condensed. The Basin Region of the western highlands, the basin north of the Himalaya Mountains, and the Andine desert, are examples showing the effects of mountain barriers. The mountains reach higher than the rain winds. The two African deserts and much of the Mexican coast show the effects of hot inland regions. The ocean winds that penetrate these regions are warmed and not cooled, and therefore they are relatively drier.

Snow.—When the condensing vapor freezes before it

can gather into drops, *snow* results. It is evident, moreover, that snow cannot form unless the temperature is as low as 0° (32° F.). If condensation takes place very slowly in still air, the frozen droplets aggregate into beautiful crystalline forms,[12] but if condensation is rapid, each flake is a tangle of broken crystals.

Inasmuch as snow depends on a low temperature, it is evident that the distribution is governed both by latitude and altitude. In polar regions snow covers the ground the greater part of the year, and at a little distance from the sea it never melts. In equatorial regions the line of perpetual snow is about sixteen thousand feet above sea-level ; in temperate latitudes it varies from seven thousand to twelve thousand feet.

Hail.—Hail consists of pellets of ice, formed in the air, and a shower of them constitutes a hailstorm. Usually a hailstorm consists of alternate shells of snow and crystalline ice.[13] In some instances sharp, dog-toothed crystals of ice project from the outer surface. Hailstones vary in size from tiny pellets to masses an inch in diameter. Larger stones occur, but they are formed by the cohesion of small ones. Hailstorms are more frequent in warm weather than in cold. For reasons unknown certain localities are especially subject to them. They very frequently accompany thunderstorms.

QUESTIONS AND EXERCISES.—Find the annual rainfall of the neighborhood in which you live by striking an average of the yearly precipitation for at least ten years. (*The statistics may be learned from the nearest Weather Station.*)

Make a record of the early and late frosts for the year. What fruit crops are injured by killing frosts in the neighborhood in which you live ?

Learn, from the nearest Weather Station, the months in which the greatest amount of rain or snow falls ;—the least.

What crops or plants of commercial value would suffer or perish

if the rainfall in the State in which you live were decreased one-third?

Note the character and kinds of cloud visible during several days; at what time were stratus clouds visible?

Explain how smoke may gradually gather cloud matter. Why is this most apt to take place toward evening?

The receiver of a rain gauge is a cylindrical cup four inches in diameter. For convenience of measurement the water caught is poured into a glass tube one inch in diameter: a depth of one inch of rain in the receiver will make how many inches in the tube?

Explain how a crust forms on the surface of snow.

At a convenient opportunity, catch flakes of snow on a piece of black cloth; examine them with a magnifying-glass and make drawings of their shapes. *(Observe the conditions noted on p. 243.)*

COLLATERAL READING AND REFERENCE

TYNDALL.—Forms of Water.

U. S. WEATHER BUREAU.—Monthly Weather Review. Midsummer and midwinter issues of any year.

GREELY.—American Weather—pp. 77–81, 134–162.

WALDO.—Elementary Meteorology—pp. 142–165.

NOTES

[1] The expressions "air *absorbs* water in the form of a vapor" and "warm air can hold more water vapor than cold air" are so popular that ordinarily they pass for scientific truths. They are certainly convenient, but a moment's reflection shows them to be inexact.

[2] The phenomenon popularly known as "the sun drawing water" is due to the passage of rays of light through rifts in the clouds. The passage of the rays is marked by minute dust-moats, which reflect and scatter some of the light.

[3] At times it may be noticed that wet clothing exposed all day to the air refuses to dry. The reason is that the air is already saturated, and because of this no further evaporation can take place.

Sometimes dew forms copiously with but a slight fall of temperature, while perhaps on a following night, none may appear,

though the temperature is much lower. An inspection of the table on p. 380, will explain how this may occur. If there were seven grains of water vapor in each cubic foot of air, a fall of temperature from 68° (F.) to 64° would be attended with dew; but if only three grains were present, the thermometer might sink as low as 40° without any sign of dew.

[5] A cloth screen within four or five feet of the ground will have the same effect.

[6] These cloud banners were noticed in the Alps by Professor Tyndall, and were first described by him. They may be often seen streaming from the summit of Tacoma, Washington, and the alleged smoke from the crater of Mount Hood, Oregon, is nothing but a similar phenomenon.

[7] This indication has had a recognized place in weather-lore for two thousand years. It is mentioned in Virgil:

Tenuia . . lanæ per cœlum vallera ferri,

MACKEREL SKY

and it is found among Teutonic peoples, as well; hence the popular saying—

Mackerel sky, twelve hours dry.

[8] Not infrequently a column of smoke, from a factory chimney or a steamer's smoke-stack, becomes the nucleus of a stratus cloud. The smoke ascends until buoyancy and gravity balance each other, and then settles in the form of a thin, flat layer. Each particle becomes a surface of condensation, and the cloud matter continues to gather until it is swept away by the wind, or the conditions are changed.

[9] The heaviest annual fall is probably at Cherrapunji, India, where the average is about 500 inches. In August, 1841, the total fall for the month was 264 inches, and in 1861 the yearly fall reached the enormous amount of 905 inches—about 2.5 inches a day! On June 14, 1876, 40.6 inches fell in twenty-four hours. In the three days ending February, 1893, an aggregate of 35.8

inches fell at Brisbane, Australia. In the United States 21.4 inches fell at Alexandria, Louisiana, in one day, and at Triadelphia, West Virginia, 6.9 inches fell in fifty-five minutes. All these instances, however, are very unusual. Commonly, not more than two inches fall in a day.

[10] The greater the distance from the coast the more abnormal is the character of the rainfall. In the Basin Region of the western United States, the rain is restricted to showers of short duration, and these often take the form of *cloud-bursts.* There is a sudden darkening of the sky, a terrific downpour of water—perhaps three or four inches in fifteen minutes—and then the sun is again licking up the water from the almost hissing rock waste. The specific cause of cloud-bursts is not known.

[11] In regions visited by periodical rains, not infrequently the air is so loaded with dust, at the end of the dry season, that the first rain is discolored and even muddy. The yellow and golden rain, once a great mystery, is commonly due to the pollen of pine. Examined under a microscope the character of this pollen is such as to leave no doubt as to its origin. Showers of frogs, fishes, and angleworms (!) have been reported, but not an instance has been substantiated. It is not impossible that a water-spout might whirl a school of fishes into the air, and then over the land, but no tornado known has been so selective as to confine itself exclusively to frogs and angleworms. The latter simply emerge from their hiding-places at the onset of the shower. Among other abnormal showers are the rains from cloudless skies. Instances are common, especially in mountainous localities. The precipitation in such cases is very slight and the showers rarely cover more than a square mile or two. The sky is cloudless merely because there are not enough drops in the air at any moment noticeably to interrupt the light.

[12] With one or two exceptions all the illustrations of snow crystals are copies of drawings made in the arctic regions by Captain Scoresby. A few drawings have been made by Professor Tyndall, and recently excellent photographs have been obtained; these show that ice-crystals and snow-flakes are not so regular nor so complicated in structure as those observed by Scoresby. In order to obtain good specimens of crystals, they must be gathered on a perfectly still day when the temperature is several degrees below the freezing-point. It is best to catch them on a

piece of black cloth, and if they are to be examined under a microscope the glass slide on which the flake rests should be covered with the same material. The crystalline forms observed in sunshine are materially different from those found in cloudy weather.

[13] The peculiar structure of hail-pellets has led to the theory that the stone has been whirled alternately into warm and cold layers of air; this is only a supposition, and concerning their formation nothing certain is known. As a theory, however, it is not unreasonable. Ordinarily, hail-storms are of only a few minutes' duration, and the amount falling is a small fraction of an inch in depth. In 1888, at Moradabad, India, hail fell to a depth of several inches, and in one district two hundred and thirty-five people were killed. In June, 1879, a storm swept over central New York and Massachusetts, during which stones seven inches in circumference fell. In July, 1880, a hail-storm destroyed the crops in the vicinity of Waupaca, Wisconsin. The shower covered an area of forty square miles. Stones from six to ten inches in circumference fell. In July, 1881, the fall of hail at Cumberland, Maine, was so great that drifts two feet deep were observed twelve hours afterward. In June, 1882, at Dubuque, Iowa, stones weighing twenty-eight ounces were found. In August, 1883, at Gray, Iowa, the drifting hail covered the fence tops. In June, 1886, so much hail fell in Grand Forks County, Dakota, that it did not all melt for thirty hours. In a single storm that passed over a small area in Dakota, a quarter of a million acres of wheat were destroyed.

CHAPTER XIV.

THE MOISTURE OF THE ATMOSPHERE. CYCLONIC STORMS

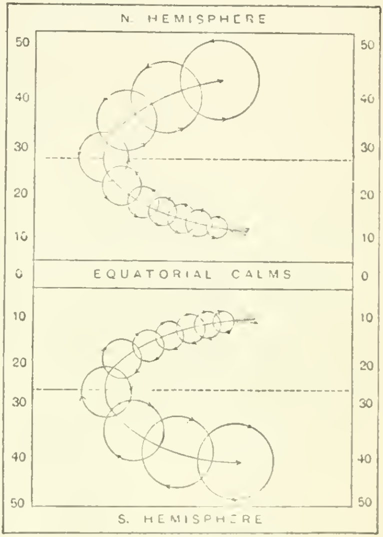
BOTH on the land and at sea there are regions of considerable area that normally are not swept by regular and constant winds. On the sea these are the calm belts; on the land they are regions from which the winds are shut off by mountain-ranges or disturbed by broad stretches of land. On the sea the shifting of the calm belts with the season brings various parts successively under the influence of the regular winds. On land the regular winds usually exist as upper currents, while at the surface the winds are local and variable; the upper currents, moreover, are so high that they are too cold to contain much moisture.

STRATUS CLOUDS DISTURBED BY AN UP-DRAUGHT

Such regions do not receive seasonal rains. The land areas, in some instances, receive none at all, except from an occasional cloud-burst; but in many cases a considerable rainfall results from the movements of local winds. That part of the United States east of the Rocky Mountains is an excellent illustration. It receives no moisture directly from the constant winds; yet about every part of it east of the 2,000-foot contour is so generously supplied

with rain that it is one of the most productive regions of the world.

Whenever a local wind occurs, one of two conditions is pretty apt to exist. Either there is an up-draught *toward* which the wind is blowing, or else there is a great accumulation of air *from* which the air is spreading outward. These local disturbances constitute the conditions popularly known as *storms*. Moreover, in either case the movement of the air sooner or later develops into a whirl. The wind that blows toward an up-draught or a depression forms a *cyclone;* that which blows outward from a high bank of air, an *anticyclone*. These disturbances originate both on the land and at sea. They are usually indicated by a changing barometer; hence a cyclone is often described as an area of low barometer—or simply a "Low"—and the anticyclone, one of high barometer. As a rule both the cyclone and the anticyclone are local disturbances, and therefore they are carried along by the great currents of the air, just as an eddy formed in a river is carried along in its flood.



NORMAL CYCLONE TRACKS

Cyclonic movements therefore travel westwardly in low latitudes and eastwardly in latitudes beyond the tropics, because these are the prevailing directions of the winds.

Because of this fact, when a cyclone has once formed, the track along which it is likely to move can be predicted with considerable accuracy.[1] The direction of the whirl has been learned by experience: in the Northern Hemisphere it is opposite that of the clock's hands; in the Southern Hemisphere, the reverse.[2] A knowledge of these facts enables the mariner to avoid a cyclone, and also to steer out of it when overtaken by one.

Tropical Cyclones.—Tropical cyclones usually originate within a few degrees of the equator. They are the *hurricanes* of the West Indies and the *typhoons* of the China Sea. The storm area extends over a surface varying from a few hundred to more than a thousand miles in diameter. The preceding illustration, p. 249, shows roughly the track which, ordinarily, one of them follows. What is its direction in tropical latitudes? in latitudes beyond the tropics? Note the direction of the whirl in each hemisphere. It rarely extends beyond the 60th parallel.

"STREAMERS" OF CIRRUS CLOUDS —THE FORECAST OF A CYCLONE

The real beginning of the tropical cyclone is the dead calm that for a few days precedes the disturbance, for it is only when the air is in a state of rest that the necessary conditions can obtain.[3] The first essential condition is the overheating of the air next the sea—precisely the same condition that formed the beginning of the desert whirl (p. 224). But while the stratum of air that causes the desert whirl is only a few hundred feet in height and involves a very small area, the atmosphere disturbed by the tropical cyclone is, perhaps,

several thousand feet high and many thousand miles in extent.

The longer the sun beats down on the glassy surface of the water the greater will be the energy of the storm when it begins. Moreover, there is one element present in the tropical cyclone that is not found in the case of the desert whirl—namely, *the vapor of water*—and this is the most important distinction between the two. Finally the equilibrium becomes so unstable that a slight up-draught of air occurs where the resistance is least. The moment this occurs, the rising air already near the dew-point is chilled by its own expansion, and a part of its moisture is precipitated. The fall of rain sets free an enormous amount of latent heat, and a furious up-draught at once takes place.

It is the latent heat of the moisture set free that gives to the cyclone its great energy. This indeed is its fuel, and so long as the supply lasts, just so long will the cyclone continue. The ascending air at first is very moist and tolerably warm. But after its moisture has been condensed the latent heat set free renders it dry and very much warmer, thereby increasing the up-draught.

The nearer the centre of the cyclone, the stronger is the wind. The "eye" of the storm, or the centre of the whirl, is the up-draught of the cyclone, and here brief intervals of sunshine alternate with torrents of rain. In the centre of the storm the barometer stands lowest—perhaps two inches lower than it is beyond the edge of the storm.

The path of the cyclone seems at first to be one of unusual shape, but when examined in relation to the prevailing winds the mystery disappears. It is not unlikely that the temperature of the upper air has much to do with the northerly tendency of the cyclone. Because cold air is relatively heavier than light air, the colder the upper air that surrounds the up-draught, the more vigorous will the

latter be. In the Northern Hemisphere the colder air lies to the northward of the storm, and this will be the direction of least resistance.

Knowing the direction of the whirl and the path of the storm, it is not difficult to lay the course of the vessel out of the way of the cyclone. For this purpose "storm-cards," or diagrams similar to that on p. 263, are convenient. The distance of the storm-centre can be estimated only to a rough degree, but the bearings can be obtained with a high degree of probability. Facing the wind the storm-centre is on the right hand.[4]

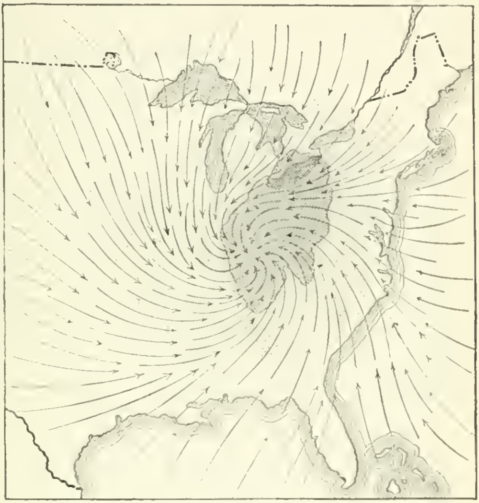
Winter Cyclones.—Some of the fiercest storms of the higher latitudes, however, do not originate anywhere within tropical regions. These are the extra-tropical or winter cyclones, and the fierce winter storms of the North Atlantic Ocean are examples. It is evident that these storms cannot originate in a dead calm, because there is no long-continued calm weather where they form; and it is equally apparent that they are not formed by the overheating of the air next the surface of the water.

It is thought that these storms result from the intrusion of cold, north winds into the region of warm and moist air, to the southward. In any case the condensation of moisture creates an up-draught that quickly develops into a whirl. But if, at the time of intrusion, the cold air takes the upper position, the equilibrium becomes much more unstable, and the storm very likely develops into one of great fury.[5]

Land Storms.—The occasional local squalls excepted, all the storms of the land are cyclonic in nature, and except in violence they do not differ materially from the cyclones of the sea. In nearly every case they follow the same courses that are taken by the latter—westerly in tropical and easterly in temperate latitudes.

Since the establishment of the various weather bureaus, the storm-tracks have been closely studied, and it is found that most storms follow certain lines or belts.

In the United States two storm-tracks are apparent.[6] The lesser number follow the trend of the Atlantic coast. The storms usually overlap the shore and the coast plain, but they seldom extend west of the Appalachian highlands. These storms belong to the class of West Indian cyclones. They originate in the Caribbean Sea, and turning northward, finally reach the latitude of the Middle Atlantic coast.



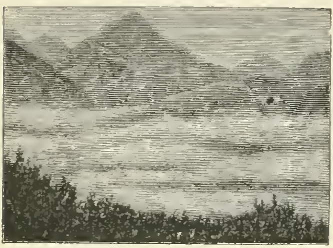
A STORM, OR AREA OF LOW BAROMETER

The shaded part is the area of rain; the dotted region the area of cloudiness. The arrows fly with the wind.

Most of the storms that prevail in the United States form near the great highlands of the west—very frequently near the eastern base of the Rocky Mountains, crossing the continent in a northeasterly direction. These storm-tracks have a distinct tendency to shift north or south with the apparent motion of the sun, the belt being a little farther north in summer than in winter. The valley of the St. Lawrence River and the basin of the Great Lakes is a common track.

Although they are sometimes accompanied by local squalls, land storms rarely exhibit the fury of ocean cyclones. The area of the storm is usually larger, but the wind seldom attains a velocity greater than forty miles an hour. The storm-centre is distinct, but the barometer may not fall more than half an inch.

Clouds, and rain or snow, accompany the majority of storms, but the area of rain does not always cover the whole extent of the storm; as a rule, most of the cloud area, and the rain as well, occur in front of the storm-centre. With the passage of the latter there are occasional hard showers in which the rain falls almost vertically, or perhaps drives slightly toward the east. These are the "clearing showers."



CLEARING WEATHER CLOUDS

Because the wind blows toward the storm-centre, it is evident that storms of the second class will be preceded by easterly and will clear with westerly winds. Those from the West Indies will begin with northeasterly and clear with southwesterly winds—the "nor'easters" and "sou'westers."

In some instances general storms are accompanied by disturbances of a very violent character. Of these the most important are thunder-showers, cold waves, and tornadoes and waterspouts. Thunder-storms and tornadoes are local in character, and often occur independently of general storms. Waterspouts and tornadoes are local, the former being confined to the water. Cold waves are general.

Cold Waves.—Just as the trough of a wave of the sea is followed by the crest of another wave, so in the aërial

ocean an area of low barometer is followed by one of high barometer, and if the latter be an anticyclone of cold air the result is a *cold wave.*

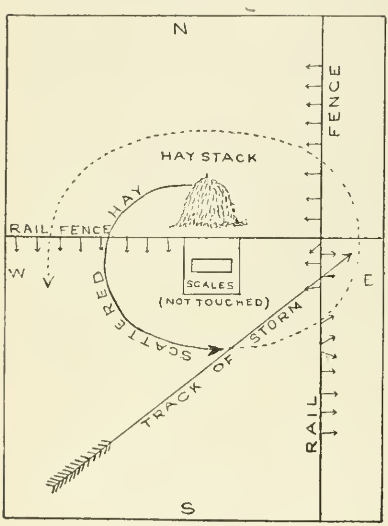
Not infrequently it happens that the barometer is considerably higher on one side of a storm-track than on the other. In such a case, it is evident that most of the air flowing in to fill the depression will come from that side on which the barometer is the higher. If the air is drawn in from the south side, it is pretty apt to be a mass of warm, moist air, and the farther north the storm track, the higher in latitude will the body of warm air intrude.[7] On the contrary, if the bank of cold air lies to the northward, the depression will fill chiefly with cold air from this direction.

In summer neither the cool air nor the warm air, following the passage of a storm, varies much more than eight or ten degrees from the usual temperature. In winter, however, if the storm-track lies well to the south a large volume of very cold air will be drawn far to the south and the temperature may fall forty or fifty degrees in a day's time, or even in a few hours.[8] Ordinarily, the cold wave flows in not more forcibly than a brisk wind, but occasionally it advances with the force of a hurricane, lowering the temperature to thirty degrees or more below zero (F.). In such cases the cold wave is called a *blizzard*[9] and it is marked by a furious downfall of snow.

Tornadoes.—Tornadoes are whirling storms of the land. Though they cover a smaller area than any other storm, they are probably the most violent atmospheric disturbances known.[10] The path of the tornado seldom exceeds thirty or forty miles in length, while the destructive part of the whirl is not more than a few rods in width. Like other cyclonic disturbances, the tornado is formed in an area of low barometer. Seen at a distance of one or

two miles, the tornado appears as a dense, black, funnel-shaped cloud hanging from rapidly whirling clouds above. The funnel is the centre of the storm, and so rapid is the whirl that it forms almost a vacuum. The rotatory velocity of the wind is thought to be not far from two miles a minute.

Between the terrific wind and the vacuous centre nothing can withstand the force of the tornado. The stoutest tree-trunks are twisted as though they were ropes, and in many instances pulled clear out of the ground. Buildings in the way of the funnel-cloud burst into pieces outwardly the moment the latter envelops them; heavy locomotives are lifted from the railway track; and iron bridges are blown from their foundations, twisted into shapeless tangles, and carried long distances. Another noticeable feature is the lane or "wind-road" made when a tornado passes through a forest.



A TORNADO TRACK.

The position and direction of the rails show the direction of the whirl.

A close study of several hundred tornadoes in a measure has shown the manner in which they originate. At the beginning of a storm it sometimes happens that a great volume of cold, dry air lies on one side of the disturbance, while a mass of warm, moist air lies on the other side. Such a con-

dition, indeed, is not infrequently the immediate cause of the storm.

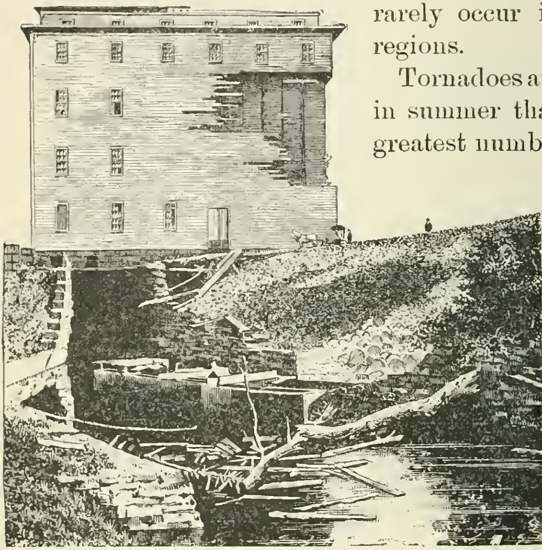
During the progress of the latter large volumes of cold air are whirled into regions of warm and moist air. Now, if the heavier cold air lies next the earth, no disturbance follows. But if it comes to rest on the top of a thick layer of warm air the case is different. The conditions are those

A TORNADO AND ITS FUNNEL CLOUD.

of unstable equilibrium, and the latter will sooner or later be upset. There results an up-draught of warm air, and soon the whirl is in full vigor.

In about ninety-five per cent. of all the tornadoes studied the whirl accords with that of other storms in the Northern Hemisphere. Almost always they move from the southwest to the northeast.[11] In nearly every instance thus far recorded the tornado track lies south of a general storm.

All parts of the United States are subject to tornadoes, but they are most prevalent in the central part of the Mississippi Valley. West of the 102d meridian they are extremely rare, because there is so little moisture in the atmosphere. There is also a belt south of the Ohio River, in which they are infrequent. They rarely occur in mountainous regions.



EFFECTS OF A TORNADO.

Tornadoes are more frequent in summer than winter. The greatest number occur in May, and more occur in May, June, and July than during all the remaining months. They are more frequent in the afternoon than in the morning, and rarely occur at night.

Waterspouts.—A waterspout is a whirlwind of the sea or other large body of water. The whirl is so rapid that the water is carried upward to fill the vacuous centre. The lower part of the waterspout is probably a nearly solid column of water; the upper part is a rapidly whirling mass of spray. Waterspouts are most common in the region of cyclone tracks—especially along the track of the Gulf Stream. It is usually asserted that the water that composes them is fresh. This is not always the case,

however; in many instances it is salt—sea-water, pure and simple. In the lower part the column is not more than ten or fifteen feet in diameter; in the upper part it is whirled into a balloon-shaped cloud of spray and mist several hundred feet in width.

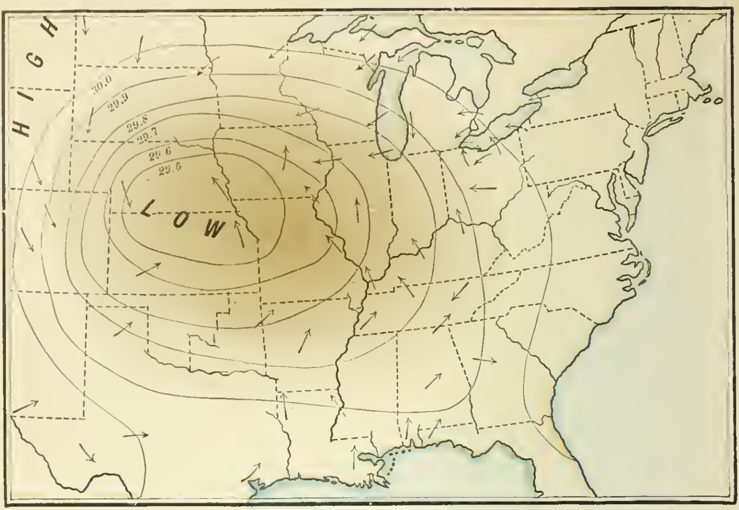
The *white squall* is similar in origin to the whirl that results in a waterspout; in fact, it may properly be called a fair-weather whirlwind of the sea. It is sufficiently violent to whirl a considerable volume of sea-water into spray, but hardly strong enough to form a waterspout.

Weather Forecasting.—Knowing the laws of storms and normal atmospheric movements, it is not a difficult matter to predict weather conditions with considerable accuracy. In the temperate zones weather conditions originate to the westward or southwestward of the observer; in tropical regions, they progress from the eastward.

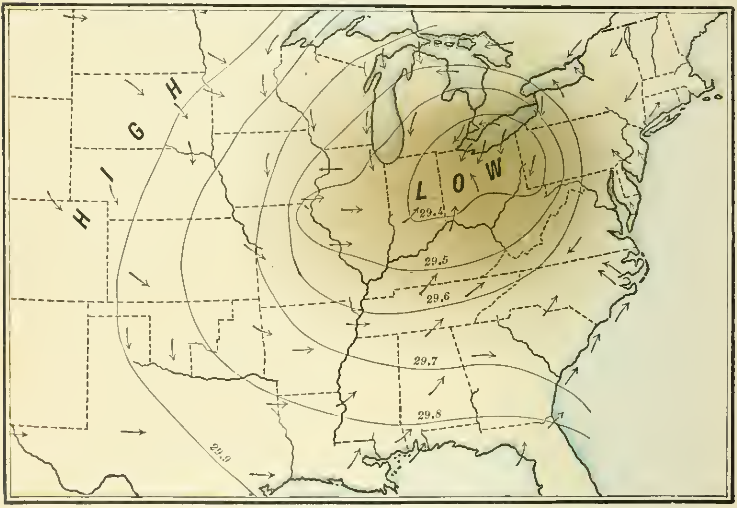
Except in the extreme southern part, where disturbances are occasionally tropical in their movements, the weather of the United States is essentially of the westerly type. That is, all disturbances progress from the west or southwest to the east or northeast.

The United States Weather Bureau [12] was organized for the purpose of protecting agriculture, navigation, and commerce by furnishing information of coming storms, dangerous coast-winds, threatening floods, cold waves, and killing frosts. Scattered over the whole territory in selected locations are upwards of six hundred observers who, twice a day, at the same actual time, observe temperature, barometric pressure, relative humidity, direction of wind, amount of rain or snow, etc. These results are telegraphed to Washington and entered upon a weather map.

Lines are drawn through localities of equal barometric



STORM CENTER: FIRST DAY



STORM CENTER: SECOND DAY

pressure, and also through localities having the same temperature. The former are *isobars*, the latter *isotherms*. In this manner areas of high, normal, and low barometer are readily mapped and located. When the direction of the wind is plotted it will be found that it is everywhere blowing toward the area of low barometer.

Twelve hours afterward, when a new set of observations is plotted, it will be found that the area of low barometer has advanced eastward with about the velocity of an ordinary express train. With this information both the direction and the velocity of the storm can be quite accurately forecast for the succeeding twenty-four hours. Practically all general storms begin with easterly and clear with westerly winds.

About ninety per cent. of the predictions may be verified and the number actually verified is very close to the possible limit. Failure of verification is due to several causes—the sudden swerving of a storm from its track, the dissipation of a storm once formed, and the unforeseen development of a local storm. The shifting of a storm one hundred miles on either side of its predicted track may nullify the forecasts over a very large area.

QUESTIONS AND EXERCISES.—Why does the wind blow toward a low and away from a high barometer?

Why do cyclonic movements of the wind move toward the west in tropical, and toward the east in temperate latitudes?

Why does the water flowing out of a sink through a discharge-pipe at the bottom form a whirlpool?

In the map at the top of p. 260, near what city is the centre of the storm? What is the direction of the wind at New Orleans and Baton Rouge?—at St. Louis and Cairo?—at Chicago and Davenport?—at Duluth?—at Cheyenne?—in the greater part of North and South Dakota?

Name one or two places at or near which the barometer is 29.5 inches; 29.7 inches; 29.9 inches; 30 inches.

About how far has the storm advanced at the time of observation on the second day?

Note the direction of the wind at Pittsburgh, Cleveland, Wilmington, N. C., Cincinnati, Indianapolis, Chicago, Springfield, Ill., Milwaukee, New Orleans, Mobile and Little Rock.

The wind whirls warm, moist air from the south to colder, northerly latitudes; what will be the effect on the moisture?—on the temperature of the region over which the storm passes?

In what position, with reference to the storm centre, is most of the rain, as indicated by the shading?

Whence comes the air in the western part of the whirl—from northerly or from southerly regions?

Will it probably be colder, or warmer? Why?

Make a forecast for Cincinnati for each of the two days.

Make forecasts for New York, Denver, and Chicago for the third day.

COLLATERAL READING AND REFERENCE.

GREELY.—American Weather—pp. 178-272.
UNITED STATES WEATHER BUREAU.—Daily Weather Maps.

NOTES

[1] In the tropics the cloud-ring rarely exceeds five hundred miles in diameter, and the circle of dangerous winds is scarcely more than half as great. In higher latitudes, however, the diameter of the storm increases. The wind is more violent in tropical, and less severe in higher latitudes.

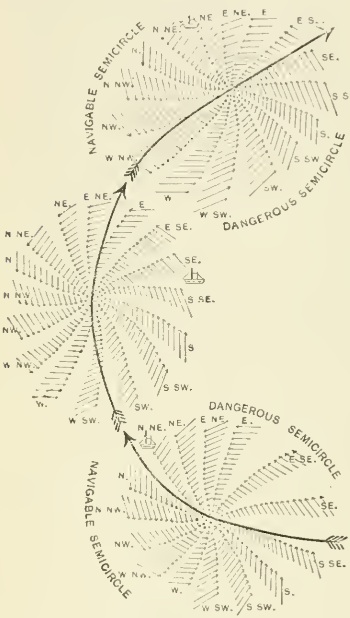
[2] The direction of the whirl is thought to result from the conflict of winds as they approach the up-draught. Of all the currents setting toward the storm-centre, the northeast Trade Wind is the strongest. As it approaches the storm-centre it is opposed by weaker winds from the north, northwest, and west. As a result, the Trade Wind is bent toward the east and forced to rotate in the manner described.

[3] The barometer gives first warning of the approach of the cyclone. During the few days preceding, the barometer is perhaps above its normal height and the weather pleasant and clear. Sooner or later the barometer begins to show signs of unsteadi-

ness, and at the same time a long, low, ocean swell becomes perceptible. Possibly a streamer or two of cat-tail clouds pointing toward the zenith is seen in the south or southwest, and a whitish arc near or on the horizon indicates the bearing of the centre. In a few hours or less the barometer begins to fall—slowly at first, and then more rapidly. A halo gathers around the sun or the moon ; the ocean swell increases, the sky grows purple, and fitful puffs of wind come from the north. There can no longer be any doubt of the approaching storm, and the prudent master has already made everything snug and ready for the coming blow. Soon a heavy, mountainous bank of cloud looms up from the horizon. This is the cloud-ring that marks the edge of the storm, and the circle of dangerous winds is not far away. Finally the wind, already very squally, bursts into a gale, and veers to the northward, and soon the storm is on, in full force. If, by any means, the course has not been altered, or if, through accident, the ship is carried with the wind, the latter will increase to hurricane strength, and not even the smallest storm-sail will stand against its force. Soon, in almost a twinkling, the wind lulls and the ship is in the eye of the storm. Then the sky alternates between inky blackness, with terrific down-pours of rain, and moments of misty, yellow light. Perhaps half an hour passes, and the opposite side of the cyclone strikes the vessel. At that moment the wind again bursts upon the ship from the opposite direction. Nothing but the stanchest vessel can ride through such a storm. A square-rigged ship is apt to have her yards stripped off, even if the masts are not snapped.

[4] The accompanying storm cards are adapted to use in any cyclones of the northern hemisphere ; the upper diagram is available for the route between New York and English ports. The small arrows fly with the wind ; the long arrow represents the storm track through the belt of latitude to which the diagram applies. For West Indian hurricanes note that the storm track recurves as follows : June and October, latitude 20° to 23° ; July and September, latitude 27° to 29° ; August, latitude 30° to 33°. When a falling barometer and other signs indicate the approach of a cyclone, select the diagram that applies to the latitude and plot the position of the ship according to the direction of the wind. In low latitudes, for instance, the wind is N NE ;

the vessel is then in the position that is shown on the lower diagram, and is in the dangerous semicircle. If possible it is best to lie-to (on the starboard tack), and observe the wind ; if (*a*) it freshens *without shifting*, the vessel is certainly in the storm track. In this case the navigator keeps off, with the wind on the starboard quarter, holding to the course. (*b*) *If it shifts to the right*, the ship is to the right of the storm track and should be put on the starboard tack, making as much headway as possible until obliged to lie-to. (*c*) *If it shifts to the left*, the ship is on the left of the storm track and should be brought about until the wind is on the starboard quarter, lying-to on the port tack if necessary. In scudding, the wind should be kept always on the starboard tack to run out of the storm. If the vessel is in the latitude where the cyclone probably recurves (according to the month) the middle diagram is applicable. Suppose that the wind is S E ; the vessel then has the position marked in the middle diagram. It is on the right of the storm track and should run out as in (*b*), previously noted. In high latitudes the upper diagram is indicated. Suppose that the wind is N E. The ship then has the position shown to the left of the storm track, in the navigable semicircle, and should be brought about as in (*c*), previously noted. In any case oil may be used to prevent the waves from breaking over the vessel.



STORM CARDS.

[5] It is unstable because the cold air is resting on a layer of air that is specifically lighter, and when the latter is pressed upward it soon develops into a whirl. Winter cyclones are not confined to definite localities, as are tropical cyclones, and in

comparison with the latter their tracks are erratic. Their general direction is easterly, however.

[6] In very many cases a land-storm may originate at sea and finally end somewhere at a considerable distance inland. Many West Indian hurricanes sweep into the Gulf of Mexico and thence into the Mississippi valley. On the other hand, there are many —perhaps a majority of north Atlantic storms—that begin far in the interior of the continent. In many instances storms have originated somewhere in the Pacific, crossed the United States, and the Atlantic, finally disappearing in the interior of Eurasia. Many of the cyclonic storms of the Pacific Coast of the United States travel southward between the Coast Range and Sierra Nevada Mountains. In some instances the storm is dissipated in the arid region to the southward, but occasionally a cyclonic disturbance finds enough moisture to enable it to pass into the Mississippi Valley.

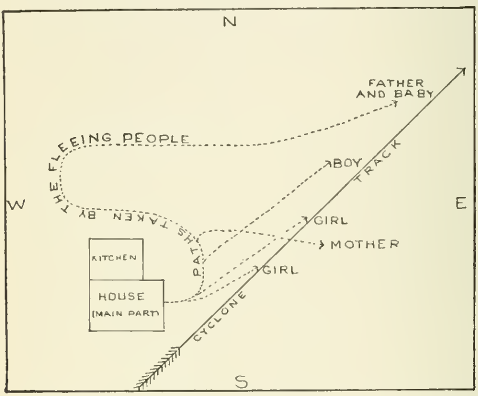
[7] Under such conditions a warm wave results. Although with respect to temperature, the difference between warm waves and normal weather is not so great as that between cold waves and normal weather, yet the former are far more fatal. In all the densely populated parts of the country the advent of a warm wave is marked by an enormous increase in the death-rate. During several warm waves that, in July, 1881, covered the Mississippi Valley, there were more than one thousand deaths from sunstroke—probably a greater number than have resulted from the cold waves of a score of years. Warm spells may result from other cases. The typical "warm wave" is the result of settled conditions, and not disturbances. The air resting upon the given area without being disturbed in the course of two weeks becomes intolerably hot.

[8] A cold wave that occurred in January, 1888, is an example of the effects of the translation of cold air from the extreme north. At Helena, Montana, the temperature fell fifty degrees in four and one-half hours, and sixty-four degrees in less than eighteen hours. At Crete, Nebraska, the thermometer fell eighteen degrees in three minutes. This wave covered almost the whole United States, carrying freezing weather into Florida, California, and southern Texas. In March, 1887, a cold wave, extending along the valley of the St. Lawrence River, was marked by a fall of temperature ranging from fifty to seventy-

one degrees in twenty-four hours. In Denver, January 15, 1875, there was a drop in temperature of forty-eight degrees in one hour.

[9] This term was first noted in the records of an exploring party which, in 1747, wintered on the shores of Hudson Bay, at a place now called York Factory. It was introduced as a technical name into the weather service in 1876.

[10] General A. W. Greely, U. S. A., notes twenty-five tornadoes, in which the aggregate damage reached the sum of $15,000,000, while the loss of life was nearly fifteen hundred. Concurrent with a storm that in February 9, 1884, crossed the United States, there were sixty distinct tornadoes. On that day eight hundred people were killed, twenty-five hundred were wounded, and more than ten thousand buildings were destroyed.



[11] The story illustrated in this cut is a grewsome summary of horrors. The house was surrounded by a grove of trees. To the east of the house the trees were felled and twisted from right to left; those west of the house were untouched. The house itself was demolished and the debris hurled into the creek-bed near by. When the tornado cloud swooped down upon the house, the family fled for their lives, but unfortunately in the wrong direction. At first they ran northward, a direction of safety. Then, one after another, they turned eastward—first a little girl, who was instantly killed; then an older boy and a girl, who were bruised and partly stripped of their clothing. The mother ran directly into the whirl and was found crushed and mangled against the trunk of a tree. The father, with the babe in his arms, had reached a place of absolute safety, but in his fright turned eastward and ran into the whirl. They were

picked up by the wind, thrown several hundred feet, and instantly killed. An inspection of the accompanying illustration shows that the safest path of flight is toward the northwest or the southeast; to the southwest or the northeast is one of the greatest danger.

[12] In 1853 the necessity for a weather bureau was urged by Commander M. F. Maury, but it was not until after his death that systematic land observations were carried out. The first organization was effected by General Myer, U. S. A., Chief Signal Officer, who trained the rank and file of his department to make weather observations. Since that time the Weather Bureau has been attached to the Department of Agriculture and placed in charge of its Secretary. Most of the European nations have established similar bureaus, and daily observations are made on all transatlantic steamships. So complete are these records that scarcely a storm occurs in the North Atlantic which is not followed and its path predicted with a high degree of probability. Flags (or sometimes painted cylinders and cones) are displayed on public buildings in nearly every town in the United States and Europe. For land service these flags are commonly used. A square white flag denotes clear weather; a blue flag, rain or snow. Temperature is indicated by a triangular blue flag. Above the square flag it denotes higher temperature; below the square flag, lower temperature; its absence denotes no change in temperature. Whenever the temperature falls twenty degrees or more (sixteen degrees in the northern States) if the mercury sinks as low as 32° (F.), it is technically a cold wave, and its approach is indicated by a white flag containing a black square. It is commonly called the "black flag." A fifth flag is sometimes employed to indicate local storms. For the benefit of mariners a Monthly Pilot Chart for the North Atlantic is published by the United States Hydrographic Office. This shows storm tracks of the preceding month, and the position of ice, fog, floating wrecks (called "derelicts"), and other obstacles, for the current month.

CHAPTER XV

ELECTRICAL AND LUMINOUS PHENOMENA OF THE ATMOSPHERE

ELECTRICITY is a form of energy that is manifested chiefly by its effects; of its actual nature practically nothing is known. The laws pertaining to it are fairly well known, however; and, like most of the other forces of nature, it is a most useful servant when under intelligent control. In the slender thread of the incandescent light and the carbons of the arc light it appears both as light and intense heat. Passing through insulated copper-wire that surrounds a core of soft iron, it converts the latter into a magnet, and thus harnessed it becomes a generator of great power. Electrical energy seems to be a form of motion, and it may be produced by motion. It is manifest not only in the earth and the air, but in space as well.

The fundamental laws of electrical energy are not difficult to understand. If a pith-ball, suspended by a silk fibre, be brought near a piece of hard rubber, or vulcanite, that has been briskly rubbed by flannel, the ball will at first cling to the vulcanite and then immediately be repelled from it. If another ball, electrified in a similar manner, be brought near the first, the two will vigorously repel each other.[1] If, however, the second pith-ball be electrified by a piece of glass rubbed with silk, the two balls will then show a strong attraction for each other.

Such an experiment demonstrates the principal laws of electricity. *Bodies similarly electrified repel; bodies dif-*

ferently electrified attract one another. The electricity developed when glass is rubbed with silk is called *positive*; that produced by rubbing vulcanite with flannel, *negative.*

Electricity passes quite freely through metallic substances, but with difficulty through such material as silk, wool, gums and resins, dry wood, and dry air. When, however, the electric force is so great that it will pass through these it is said to have a *high potential*, just as steam confined within a boiler is at high pressure.[2] The

LIGHTNING

From an instantaneous photograph by W. F. Cannon.

"sparks" produced by rubbing sealing wax or vulcanite with flannel are of moderately high potential.

To the electricity of the air and the earth many of the most marvellous phenomena are due. In the simplest form we see its effects when tiny sparks result from rubbing the long knap of woollen cloth or the fur of an animal pelt; we see its grandest effects when great flashes of lightning forge across the sky. The electricity of the air is usually of high potential; that which forms a flash of light-

ning is of exceedingly high tension. Next the earth, however, the electricity of the atmosphere is not commonly noticeable, especially if the air is moist. At considerable elevations, or at times when the air is very dry, its presence becomes marked. The hair of the head crackles as a comb is drawn through it, and tiny sparks are given off when woollen clothing is rubbed. In the dry summer climate of deserts, the hair of horses' tails stands out like bushes, and their manes are like fright wigs; sparks half an inch long may be drawn from a metallic body insulated from the ground.

Ordinarily the electricity of the air is positive, but, with much moisture present, it may be negative. Just before the beginning of a gentle shower it often becomes negative, and during a heavy storm it frequently changes from positive to negative and *vice versa* very rapidly. In such cases the character of the electricity may vary in different places; that is, it may be positive at one locality and negative at another, only a few miles distant.[3]

Neither physical nor chemical change in a substance takes place without the development of electric energy. Friction likewise is a potent factor in its generation. The flowing of water; the chafing of the winds against the earth's surface; even the friction of the air against itself produces it copiously. Evaporation and condensation are attended by an electric disturbance; and inasmuch as an enormous amount of the vapor of water is constantly arising from the earth at one place to be condensed,[4] at another these changes in physical form, together with friction, may be regarded as the chief agents in its production.

Since these factors are constantly at work, it is evident that electricity is being constantly produced. But the electricity of the air and that of the earth are unlike; the two, therefore, neutralize each other. Because moist-

ure is a good conductor, if the air be moist the two kinds of electricity readily pass, one from the earth to the air, the other from the air to the earth, until the equilibrium is restored. This transference is quietly but constantly going on, so that ordinarily there is no great accumulation of electricity. It is only when the air is very dry that the transference takes place with difficulty.

Thunder Storms.—When clouds are present in the air, however, there is often an enormous accumulation of electricity, either within or upon their surface, and the transference or exchange, therefore, may become violent and destructive. Such disturbances are commonly known as thunder storms.

When large masses of cloud hover over the earth it sometimes happens that they are differently electrified. Under such circumstances the two clouds are mutually attracted. The potential of the electricity is very high and the transference takes place in the form of blinding flashes of lightning.[5] Usually the interchange takes place between the two clouds, but not infrequently it is between the clouds and the earth. The form of lightning varies. The interchange takes place always along the line of least resistance, and as this is seldom, if ever, a straight line, it has taken the name, *zig-zag* lightning.[6]

Another form is known as *sheet* lightning. This interchange takes place, not along a line, in the form of a chain, but simultaneously over a large area. The discharge is not attended by a crash of thunder nor by a blinding flash of light. On the contrary there is nothing but a quivering, bluish glow that lasts sometimes for eight or ten seconds. A sheet-lightning discharge takes place usually between the earth and the clouds. The electricity is of low potential and therefore not destructive. This name is also applied to flashes of lightning that, occurring at

a considerable distance, are reflected from the under surfaces of clouds.[7] Still another form is commonly called *ball* lightning. Of this kind of discharge but little is known, and although its occurrence has been alleged for more than two hundred years, its existence is somewhat in doubt.

Occasionally the discharge takes unusual forms. Among them, but rare in occurrence, is the phenomenon known as *St. Elmo's fire*. This discharge, though best known at sea, is also occasionally observed on land. At the time of its occurrence there is usually a considerable electrical disturbance, though not necessarily a thunder-storm. Owing to the feebleness of the light emitted, it is rarely if ever noticed in the daytime. It consists of a pale, shimmering light, at the tips of the yards, spars, and from every pointed part of the ship's rigging. The glow lasts for a few moments and then the phantom light disappears.[8] In all probability the St. Elmo's fire is identical with the bluish glow that is seen when a frictional electrical machine is worked in the dark—a phenomenon commonly known from its shape as the "brush" discharge.

The Aurora Borealis. — This magnificent display, commonly called the "northern lights,"[9] is without doubt an electrical phenomenon that possibly is similar in nature to the brush discharge. It is most common in high latitudes, though it is occasionally observed between latitudes 30° and 40° N. In appearance the aurora is an arch of light stretching across the sky fifteen or twenty degrees above the horizon. It has a tremulous motion, and the upper streamers sometimes mount to the zenith.

In color the aurora varies between pale green and crimson. Sometimes it closely resembles a green curtain edged and lined with gold. Auroras are most frequent during sun-spot periods; they are usually coincident with mag-

netic storms also. In circumpolar regions they are of daily occurrence.[10] The cause of auroras is not with certainty known, but they are thought to be an exchange between the electricity of the atmosphere and that of the earth. The arch of the aurora nearly always surrounds the earth's magnetic pole.[11]

Magnetism.—A bar of steel, iron, or nickel, or a piece of lodestone[12] that has the property of attracting and holding to its surface small pieces of similar metals is called a *magnet*. Steel retains its magnetism permanently, and for all practical purposes the magnet is a flat bar of polished steel, eight or ten inches in length. Sometimes, however, it is bent into a U-shaped form called a horseshoe magnet.

When a bar of steel is magnetized, it is found that the magnetic force is not uniformly distributed throughout the bar, but is most intense at or near the ends.[13] These are the *poles* of the magnet; they are designated as positive +, and negative −, according to the direction they take when the magnet is suspended at the centre of gravity.

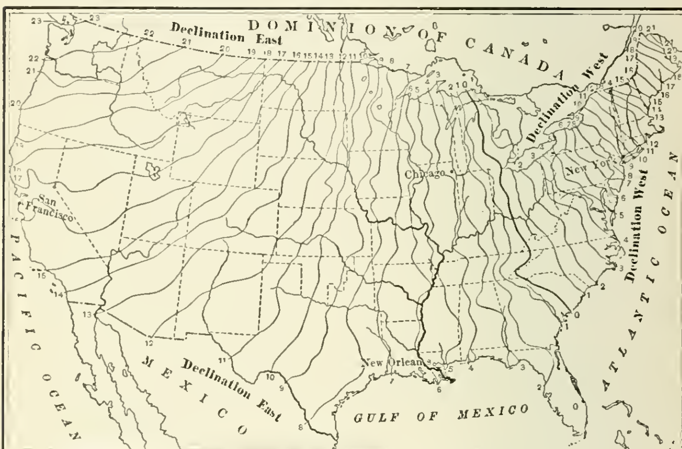
If a slender bar of ordinary steel be suspended by a hair from its centre of gravity, it will lie indifferently in any direction in which it is placed. If the bar be magnetized, however, it takes new properties. It no longer remains indifferently in any position; on the contrary it turns until its direction is nearly or quite north and south. It no longer remains balanced, but the north-pointing end dips toward the earth.

If now another bar magnet be brought near it, the latter shows no little sensitiveness. If the + end of the bar be presented to the + end of the suspended magnet, the latter will instantly turn away; if the two − ends be brought together the same thing will be noticed. On the contrary if + and − poles be brought together they are strongly at-

tracted. From these experiments the laws of magnetism are deduced. *Like magnetic poles repel; unlike poles attract.* Either pole of the magnet, however, will attract alike an unmagnetized piece of iron or steel.

It is upon these laws that the whole science of navigation by the compass depends, for the earth behaves as a magnet[14] and the essential part of the mariner's compass is also a magnet.

Magnetic Variation.—The earth's magnetic poles are not situated at the geographical poles. The magnetic north pole is situated west of Boothia Land, a few miles north of the crossing of the 97th meridian and the 70th parallel.



LINES OF EQUAL MAGNETIC VARIATION

Its position is not fixed, and it is moving in a westerly direction.[15] The position of the magnetic south pole is not known, although roughly approximated.

Because the magnetic poles are not situated at the geographic poles, it is evident that the magnetic needle can

point due north and south in but few places. In the accompanying chart, a heavy black line passes through these points. This line, called the *agonic*, is the line of no variation. West of this line the north-pointing end of the needle turns toward the east, and east of it it swerves to the west. Along each of the lighter lines the needle has the same deviation at all points, and these lines, therefore are called *isogonics* or lines of equal variation. This deviation from the true meridian is called *declination.*

Trace the course of the line of no variation.

Besides that element of magnetic force that causes the needle to lie in a nearly north-and-south direction, there is another that causes it to dip or incline one end toward the earth. This is called the vertical force, or *inclination.* Along an irregular line passing around the earth, sometimes north of the equator and sometimes south of it, the needle has an absolutely horizontal position. North of this line the negative, or north-pointing end, dips toward the earth. The farther the observer goes northward, the stronger becomes the vertical force, and when the magnetic north pole is reached the needle has a vertical position, the — pole being next the earth.

South of the magnetic equator, or *aclinal*, the conditions are reversed. The + pole dips more and more, until, at the magnetic south pole, the needle is again vertical with the + pole next the earth. A line on which the dip is everywhere the same is called an *isoclinal.*

Not only does the position of each isogonic vary from time to time, but the rate of variation is not uniform ; even at the same place the rate varies from year to year. In the northwestern part of the United States the amount of variation is at present from 3′ to 7′ ; in the southwestern part it is, at present, nothing ; in the eastern and central parts it varies from 5′ to 3′.

The deviation from the true geographical meridian also varies from day to day. Most of these variations are periodical. Some are daily, some monthly, and some yearly; they are probably caused by the daily rotation of the earth, the passage of the moon, and the annual motion of the earth. There are also irregular changes in variation which cannot be accounted for.

Such changes in variation are rarely great; in temperate and in low latitudes they cannot well be detected except by close measurements. In the vicinity of the magnetic pole, however, they are more marked. At Point Barrow and at Lady Franklin Bay, during a period of twenty-four hours, a change of nearly eleven degrees was recorded.[16]

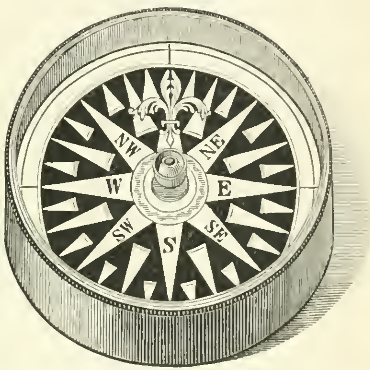
Magnetic Storms.—Not infrequently the irregular variations of the needle are so violent that they have been called magnetic "storms," and during the progress of one of these disturbances the needle is in a constant tremor. Magnetic storms seem to be closely associated with the spots that at times are visible on the surface of the sun. The sudden formation or change in the position of a sunspot is nearly always attended by great magnetic disturbances. The period when they are most frequent, moreover, corresponds to the period when sun spots are most numerous.[17]

The Mariner's Compass.—The compass is a slender bar of magnetized steel, so constructed as to balance on a pivot and turn freely upon it as well. Usually it is armed with a sliding weight, so adjusted that it exactly counterbalances the dip or vertical force, thereby keeping the needle in a horizontal position.

On land the compass is of but little practical use except in rough surveys. On the sea, however, it furnishes the only means by which a vessel may be kept continually on her course. For this reason the mariner's compass is

constructed with the greatest care and precision.[18] The needle, which consists of one or more slender bars of steel, is fastened to a circular card subdivided into thirty-two parts, on which are printed the cardinal directions. These are called *points of the compass.* The compass-box is mounted on gimbals, so that, no matter what may be the motion of the vessel, the box always swings into a horizontal position.

In going over almost every travelled ocean route, the variation of the compass changes day by day. On the regular routes of the transatlantic liners, the variation increases from about eight degrees at New York to more than thirty-five degrees at the crossing of the 40th meridian. It then decreases to about twenty degrees at Liverpool.



MARINER'S COMPASS

An ordinary pattern.

In arctic regions, where the horizontal element of force is so weak, and the dipping force so strong, sailing by compass is a very difficult matter. Not only does the variation change rapidly over short courses, but the needle becomes exceeding sluggish. On whaling vessels it is customary to attach a line to the compass-box so that the steersman, by occasionally shaking it, may better judge the course over which the vessel is sailing.

Luminous Phenomena.—Transparent as it seems, the atmosphere nevertheless does not afford passage to all the light that may be transmitted through it. A ray of light in passing obliquely is not only *refracted,* or bent out of

the direction in which it started, but possibly it is *decomposed* into differently colored rays. The distortion that one may observe by looking at an object across the top of a very hot stove, or a smoke-burning chimney is an example of refraction. On the other hand, the color effects observed when light passes through a glass prism, such as a chandelier pendant, or even the bevelled edge of plate-glass, are examples of decomposition—the beautiful display of the colors red, green, and violet, with their compounds resulting.

A ray of light striking the surface of a highly polished metal or vitreous substance is *reflected*, rebounding in the same manner as does a rubber ball thrown against the floor. The same thing occurs when the ray strikes the surface of a body of water, or even that of two layers of air resting one upon the other.

The air always contains innumerable dust-motes and particles of matter so fine and light that they seem always to float. This is seen when a few rays are admitted into a darkened room; the passage of the rays is marked by the light reflected by the motes; and it follows, therefore, that a part of the light emanating from a luminous source is always scattered. The scattering of the light in this manner is called *diffraction*. It is a singular fact, moreover, that some kinds of floating matter will scatter the blue, while other kinds scatter the red rays.

The color of the sky is thought to result from diffraction. The red rays are scattered and the blue rays ordinarily reach the eye. At times, however, when the air is heavy with dust, the sky acquires a hue that is distinctly red. This was very noticeable in 1883, after the eruption of Krakatoa; for nearly a year the sunsets were exceedingly lurid. Ordinarily, at sea, the blueness of the sky is very marked, and the color is purer than on land; with ac-

cumulating moisture, however, it may acquire purplish tints. At very great elevations, also, the blue gives way to a dead hue that approaches blackness.

Mirages.—When a layer of air rests on another of different temperature and density, the surface of contact often reflects so much light that it acts as a mirror. If the surface is lower than the eye of the observer, the reflection much resembles that produced by a body of water, and a *mirage* results. In deserts and arid regions, the illusion is so perfect that nothing but experience will enable one to distinguish the mirage from a lake. The "lake" mirages of the Colorado Desert have lured both cattle herds and travellers to their death.

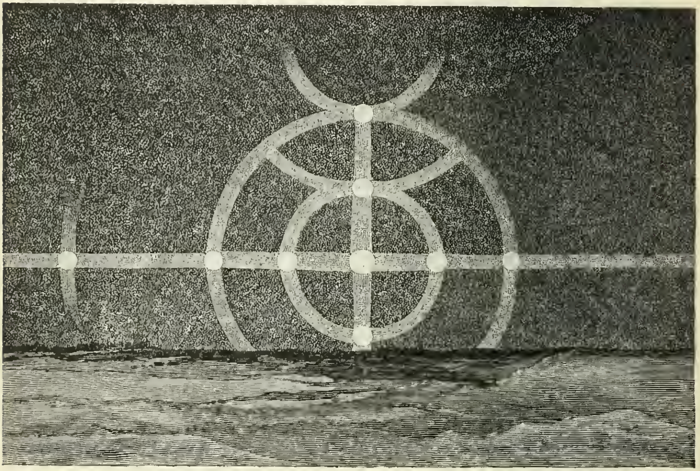
With the reflecting surface above the eye, the character of the mirage differs. Thus, at times, off the lake shore at Chicago, one may see the lighthouse and the shipping at the mouth of the river inverted in the air. If possible, illustrate this by means of a large mirror held overhead, face downward.

Still another form of mirage occurs when objects, ordinarily hidden by the earth's curvature, are brought in sight. It sometimes happens that the rays of light reflected from an object, are refracted so that they are curved slightly toward the earth, and a distant object is thereby brought to view. This phenomenon occurs at times along the Mediterranean and Red Seas, and it is not unknown along the Great Lakes. As a rule, a dry, still atmosphere is essential to the formation of the mirage.

Coronas and Halos.—The ring or rings about the sun or the moon are very common phenomena. The small rings are coronas ; the larger ones, halos. In the case of the corona, which is not of very common occurrence, there is usually a series of concentric, colored rings. These, it is thought, result from diffraction, the light being scattered

by the moisture of the atmosphere. The halo around the moon is probably caused by refraction, and it appears when the air is very moist. For this reason it is apt to portend rain or snow.

The halos of the sun, which are associated usually with cold weather, probably are caused by the refraction of the light as the latter passes through the ice crystals of cirrus



HALOS OBSERVED BY GENERAL GREELY

clouds. Frequently there are several circles. Some of them are concentric; some are tangent one to another; and some intersect one another. At the places of intersection and of tangency more light is radiated, and these spots, therefore, are sometimes very bright; they form the *sun dogs*, or *mock suns*.

Rainbows.—Occasionally, during a summer shower, when the sun breaks through a rift in the clouds, the light passes through the falling drops of water in such a way that it is not only refracted but decomposed. The resulting

decomposition is the arch of colored light that constitutes the rainbow. The bow is blue and violet on the inner, and red on the outer side. Sometimes there is a larger secondary box in which the order of colors is reversed.

The rainbow is best observed when the sun is near the horizon. The observer sees the bow when his back is turned toward the sun. The rainbow is frequently observable when heavy waves break and send spray high into the air, and also in the ascending spray of cascades.

QUESTIONS AND EXERCISES.—Verify the statements concerning the mutual attraction and repulsion of electrified bodies, observing the directions contained in note 1.

Verify the statements concerning the laws of magnetism noted on p. 273, using one or more stout knitting-needles and strands untwisted from silk thread. For observing inclination the strand of silk had better be fastened by means of a slip knot to the needle ; for the other experiments the needle may be thrust through a bit of paper to which the silk is attached. In magnetizing the needles, rub the ends only.

From the chart, p. 274, estimate the magnetic variation of the place in which you live.

At any time of their occurrence note carefully whatever you may observe with reference to auroras, mock suns, halos, and coronas.

Observe whether halos of the moon are followed by clear or by rainy weather.

Occasionally, in very dry weather the disc of the sun is considerably distorted at the time of setting ; explain why.

Explain the cause of redness that occasionally marks sunrise and sunset when the air is smoky.

The sun and the moon seem to be much larger when near the horizon than at zenith ; is this phenomenon real or apparent ? The use of a paper or other tube an inch or two in diameter will aid in the solution of this question.

Explain the phenomenon of the " sun's drawing water."

COLLATERAL READING AND REFERENCE.

WALDO.—Elements of Meteorology—pp. 166–180.

GREELY.—American Weather.

DAVIS—Elements of Meteorology.

NOTES

[1] Small pieces of cork will answer for these striking experiments, but bits of alder pith are better. In order that they may be successful the air of the room should be very dry. The pith-balls may hang from the end of a penholder thrust obliquely into the cork of a stoppered bottle. For the electrifiers, a glass lamp chimney and a vulcanite comb may be used. Each must be made *absolutely clean*, as the slight film of grease from the hands will interfere with the reaction.

[2] The potential of electricity may be also likened to pressure on water flowing through a pipe. If the pressure be low the water will flow quietly through the pipe and fall at no great distance from the end of the nozzle ; on the contrary, if the pressure be great, it will be projected to a considerable distance. In a single cell of galvanic battery the potential, about one or two volts, is so low that the electricity will not jump across a space of one thousandth of an inch ; the quantity, moreover, is very small. In an electric-light wire a current of considerable volume will leap across a space one-tenth of an inch or more ; its potential is about 1,000 to 1,500 times as great as that found in a cell of an ordinary galvanic battery, being from 2,000 to 5,000 volts. A good frictional electric machine will cause sparks to leap between points ten or twelve inches apart ; the potential is very high, but the quantity is small. During a thunder-storm a stroke of lightning may jump a distance of a mile. Not only is the quantity enormous, but the potential is so great as to be immeasurable by ordinary standards.

[3] At different localities, the character of the electricity may be so very unlike, that the earth currents are sufficient to operate telegraph wires without the aid of the batteries. In regions of dry climate such conditions are more frequent than in areas of considerable rainfall.

[4] The vapor of water is not only a good conductor of electricity, but it is an excellent storage reservoir as well. The small globules of vapor that compose the cloud mass carry each the charge of electricity upon the surface. But when a great number of these globules are condensed to form a drop of water, the surface of the drop is infinitely smaller than the aggregate surface of the

globules. The potential of the drop, in comparison with that of the globules, is enormously increased. If an electrified body, such as a vulcanite rule, is brought near a sprayer or a sprinkler the fine spray immediately gives place to large drops.

[5] The lightning itself, or rather the electricity, is not necessarily visible. The flash of light that accompanies the discharge is due to some extent to the foreign matter in the path of the discharge, heated to whiteness. The air being a poor conductor offers considerable resistance to the passage of the electricity, and is therefore intensely heated along the line of discharge. The thunder is produced in exactly the same manner as is the noise that accompanies the discharge of a firearm. The air at the point of discharge is rarefied almost to the extent of being a vacuum; the rush of the air to fill the suddenly made vacuum is accompanied by noise. The rumbling of the thunder is due partly to echo and reverberation, and partly to the fact that the sound along the line of discharge reaches the ear at different intervals—the greater the distance the longer the time required for the sound to reach the ear. Discharges of high potential only are accompanied by thunder.

[6] In paintings and illustrations it has always been customary to depict the electric discharge in the form of a zigzag line of many sharp angles. In the past few years photographs of the lightning stroke have been successfully made. One of these on a preceding page shows the fallacy of former notions on the subject.

[7] This reflection is called *heat lightning*. It is rarely ever observed except at the horizon when the latter is overcast by clouds. The reflected flashes of light are usually so far away that the accompanying thunder is not heard.

[8] While Cæsar was engaged in carrying on his military operations in Africa, he relates that, during a severe hail-storm, the spears of his fifth legion were tipped with fire. The phenomenon was undoubtedly identical with that of St. Elmo's fire. It is not improbable that the "ignis fatuus," "Jack o' lantern," or "Will o' the wisp" is a similar electric phenomenon. This is a hazy indistinct light that appears occasionally in swamps. According to tradition and fiction, the ignis fatuus is a bright light that moves rapidly from place to place mainly for the purpose of alluring unsuspecting travellers into dangerous places. As a matter

of fact, it has no great power of locomotion, and practically is stationary.

[9] The aurora is not confined to northern regions; it occurs in southern circumpolar regions as well. In the southern hemisphere, however, it is called the *aurora australis*, but the southern aurora is neither so brilliant nor so frequent in occurrence as that of the northern regions.

[10] It must not be thought that the aurora occurs at night-time only; it may take place at any time—day or night. It is not visible in day-time, however, on account of the greater brilliance of the sun.

[11] Professor Balfour Stewart has advanced the opinion that both auroras and earth currents are secondary currents due to small but rapid changes in the earth's magnetism. The body of the earth may be compared to the magnetic core of an induction coil, the lower strata being the insulating medium, while the upper strata, which are much better conductors, take the part of a secondary coil.

[12] Nearly all the elements are more or less sensitive to magnetism; iron, cobalt, and nickel possess the force most strongly, however. Bismuth and copper seem to be repelled and take an east-and-west position, or a direction at right angles to that of an ordinary magnet. Such substances are said to be diamagnetic. A piece of soft iron retains its magnetism only while it is in contact with a magnet or near to it; a piece of steel, on the contrary, once magnetized retains the property permanently. A steel bar may be magnetized by rubbing its ends with those of another magnet, or by winding several hundred turns of insulated wire about it, through which a current of electricity is passing.

[13] If the bar be a long one, or if the quality of the steel is not uniform, there are usually several supplemental poles scattered about the surface. For the same reasons a light slender bar is better than a stout one.

[14] The shape of the earth is not such that its magnetic force can possess much intensity. Several magnetic poles are known to exist, but only the two north poles of great intensity are usually charted. The pole of greatest intensity is the one commonly known as the magnetic north pole. Since its discovery by Ross, it has moved about forty miles westward. In 1879 it was approximately located by Lieutenant Schwatka in the open space

between Victoria and Franklin Straits. Its exact position has not been determined since 1831, and it is doubtful if its location at that date was so precise as might be inferred from the figures, which are expressed in minutes of arc. At that time there were no instruments sufficiently delicate for such precise determination. In 1884 the position of this pole was again approximately determined to be in lat. 70° 30′ N.; long, 96° 40′ W. The position of the magnetic south pole has not been with certainty discovered.

[15] Observations made at Paris on the movement of the magnetic north pole cover a period of more than three hundred years. In 1580, the declination at the city was 11° 30′ East. It decreased until in 1683 it was nothing, after which time the variation became west. The westerly variation increased until, in 1814, it amounted to about 22° 30′ W. Since that time it has dropped to about 22°, and, it is thought, is slowly decreasing. In 1790 the variation at Norfolk, Va., was nothing; in 1893 it was about 3° 16′ W. In New York City the variation in 1686 was 9° W.; in 1790 it had decreased to 4° 15′ W.; after this time, however, it gradually increased until, in 1893, it was about 8° 25′ W.

[16] In order better to study these variations, magnetic observatories have been established in various parts of the world. The essential part of such an observatory is a series of magnets each carrying a small mirror, mounted in such a manner that a spot of light is thrown on a sheet of photographic paper. The sheets of paper are fastened each to a cylinder revolved by clockwork, so that the spot of light traverses the whole length of the sheet in twenty-four hours, thus drawing a line upon it. If the magnet were motionless the line would be straight, but if the magnet turns even a small fraction of a minute, the spot is thrown out of position and the line becomes irregular. Usually three magnets are employed—one to measure variations in horizontal force; one for variations in vertical force; and one to measure the strength of the horizontal force.

[17] This period recurs every eleven years. In 1882 the formation of a sun spot was attended by a magnetic storm that was recorded at Point Barrow, Lady Franklin Bay, Los Angeles, Kew (London), Cape Horn, and Paris. Telegraph instruments were affected, and in some instances, long circuits were worked by ground currents. At the magnetic observatory then in Los Angeles, California,

the tremor of the magnets was so great that for several hours one of the instruments failed to make a legible record.

[18] In the Ritchie compass, now generally used in the United States Navy, the compass-box is filled with alcohol in which the card and needle almost float. The object being to relieve the bearing of the weight of the card, and thus make the needle more sensitive. It is a most excellent compass and is vastly superior to the ordinary compass formerly used. The compass of Sir William Thomson (Lord Kelvin), consists of a battery of six or more very slender magnets held in a skeleton frame. The latter is so light that the friction on the bearing is imperceptible. This compass is used in the English Navy, and by most of the trans-atlantic liners. As an efficient instrument it has no superior. The use of steel in the construction of vessels has added materially to the difficulties of sailing by compass. The hull of a steel or iron vessel has poles of intensity peculiar to itself, and these are apt to change in time, so that frequent tests of the compasses are necessary. There are various devices for obtaining the proper correction for the compass on steel vessels; a very effective method is to swing the vessel, stem and stern, along a geographic meridian and then compare the observed with the normal variation. On battle-ships either the addition or the removal of the armament, or the substitution of a steel for a wooden mast, is apt to make readjustment of the compasses necessary.

CHAPTER XVI

CLIMATE AND ITS FACTORS

THE conditions of a region with reference to its habitability constitute its *climate*, and these, in general, are the results of heat and moisture; climate, therefore, includes all the modifications of environment due to heat and cold, rain and drought. It is modified by many conditions, of which the principal are latitude, altitude, position of highlands, direction and prevalence of winds, and the inclination of the earth's axis, together with its constant parallelism to itself.[1]

Latitude.—Latitude affects climate chiefly with reference to temperature. The greater the distance from the equator, the lower will be its average temperature. The sun's rays are never vertical beyond the tropics, and in polar regions they fall so obliquely that they impart but very little heat to the surface which they strike. Illustrate this by means of the diagram on p. 294.

In going from the equator to polar regions, therefore, one will pass through about every degree of warmth from perpetual summer to the coldest winter. Within thirty or thirty-five degrees of the equator the change in temperature is not great, but beyond the forty-fifth parallel the winter climate grows rapidly cooler for every few degrees of increase.

Latitude also exerts a considerable influence on rainfall. As a rule the rainfall is greatest within the torrid zone.

In the region of tropical calms, on the contrary, the rainfall is usually deficient. These calms are regions of descending currents of the air, and the air being warmed by its descent, instead of chilled, but little rain falls.

Altitude.—The effect of altitude is much the same as that of latitude. On an average the temperature is lower by about one degree for every three hundred feet of ascent. Thus, even in equatorial regions, one may find on the slopes of snow-clad highlands all the intermediate degrees of temperature between perpetual summer and eternal winter. In Mexico the effects of altitude are finely illustrated. The city and seaport, Vera Cruz, is intolerably hot and moist, yet less than two hundred miles away, the City of Mexico enjoys a climate that is dry, cool, and invigorating. The difference is due almost wholly to its altitude—about 7,000 feet above the sea-level.

A still more striking example is found among the plateaus of the Colorado River. Hurricane Ledge is an almost vertical escarpment, 2,500 feet high, that forms the boundary between two plateaus. On the upper mesa the products are those of a temperate climate ; in the lower they are distinctly sub-tropical. It is scarcely more than a stone's throw from the former to the latter.

Position of Mountains.—The existence of high mountain-ranges often determines the quantity of rain precipitated upon the surface of a given region. In tropical latitudes rain-bearing winds blow from the east, and the eastern slopes of high ranges are therefore well watered, while the western slope is dry. In the temperate zones, on the other hand, the rain winds are from the west; and the western slopes in consequence receive most of the rain, while the eastern side is comparatively dry. Thus, in the Peruvian Andes, the rain winds deluge the eastern slope, leaving the western side practically a desert. In the

southern Andes, the conditions are reversed; the rain falls on the western side while the eastern slope is arid.

The effect of the absence of mountains is observable in Australia. Partly because of its latitude, but mainly for want of a high range, the greater part of the continent is a desert, and about the only rain that falls is precipitated on the highlands of the eastern side. In the great African desert, the few isolated ranges receive considerable rain on their summits, but none falls elsewhere.

Distance from the Sea.—The proximity of the sea exerts a marked effect on climate, both with respect to temperature and moisture. The climate of a coast region is always more equable than that of a far inland or *continental* area. The reason therefor is apparent; the air over the ocean has a much more uniform temperature than that over the land. The result is seen when the extremes of temperature are noted. For example, San Francisco and Leavenworth, Kan., have nearly the same mean temperature for the year. But while the difference between the summer and winter temperature of San Francisco is less than ten degrees (F.), that of Leavenworth is almost fifty degrees.[2]

Not all coast regions, however, enjoy a maritime climate. Because the winds of the temperate zones are, as a rule, westerly, in the eastern coast of such regions land winds are prevalent. The coast region of the northeastern part of the United States is an example. Its climate is distinctively continental, and the influence of the sea penetrates only a very few miles inland.

The climate of islands at a distance from any large body of land is always equable. The Philippines and the Hawaiian Islands are examples; although in the torrid zone, they are regions of perpetual spring, with no excesses of temperature. The Leeward and Windward islands of the

West Indian group are also examples. Though situated only a few degrees north of the equator their summer temperature is less oppressive than that of New York City.

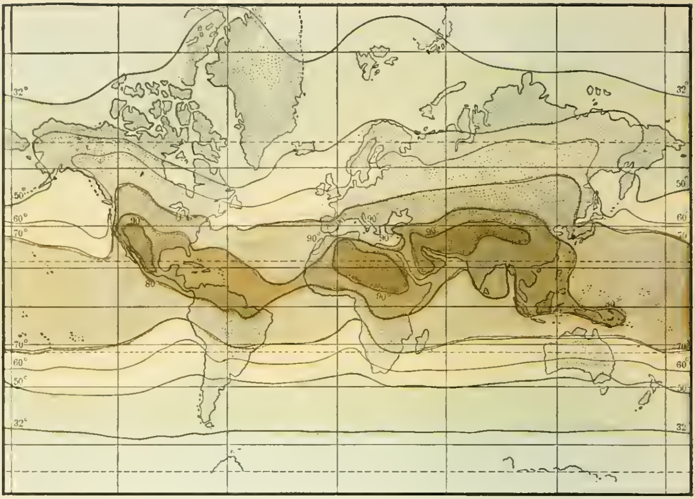
Prevailing Winds.—Winds are the chief medium for the transmission both of moisture and warmth. Cold winds from polar regions modify the excessive heat of low latitudes, and tropical winds blowing into high latitudes soften the rigors of polar climate. The mild temperature of western Europe is due largely to southwesterly winds, and the same is true of the equable climate of western North America. Not only do the winds themselves transfer a great amount of heat by convection, but the vapor of water furnishes an enormous supply. For every pound of water vaporized, enough heat is made *latent* to raise nearly half a ton of water one degree (F.) in temperature. When the vapor, mingled with the wind, is carried to higher latitudes and there precipitated, all this heat is again set free. An inspection of the chart of winds (p. 221) readily gives all the information necessary to determine roughly the climate of a country. The regions invaded by sea winds that have come from low latitudes are the regions of warm and equable climate. Inland and polar regions are areas of climatic extremes.

Changes in Climate.—As a rule, the climate of a country is constant; that is, it does not change materially except after long intervals of time. The mean temperature of any given locality rarely varies more than a very few degrees from one year to another, and the averages of long periods show still less variation. Fluctuations in rainfall and cloudiness are considerably greater than those of temperature. In regions of generous rainfall the precipitation of very wet years may be nearly twice that of very dry years, but in localities of deficient rainfall the difference may be greater.

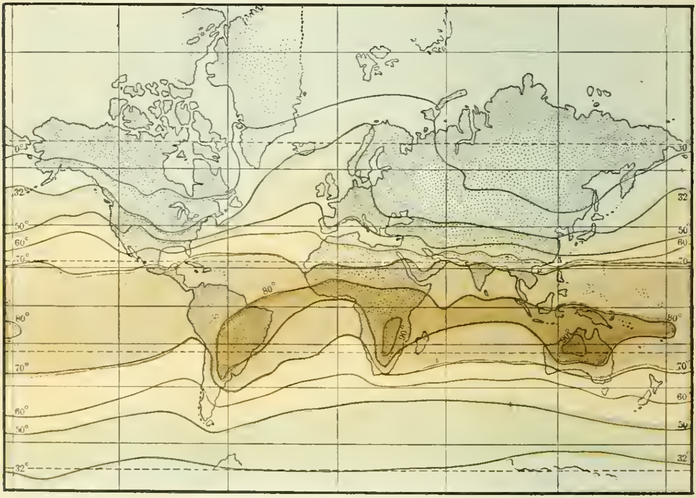
When time is reckoned by geological epochs, however, it seems certain that great climatic changes have occurred in every part of the earth, and that they have been of the most radical character. The Glacial Epoch, already described, is an example of a change in the climate that has taken place in the North Temperate Zone. It is certain that the rainfall of the Basin Region of the United States is subject to periods of oscillation. The few scattered sinks and salt lakes of the Great Basin itself are remnants of two large lakes that existed there at no very remote period, and these in turn are evidence of a much greater rainfall than the region receives at the present time.

Definite knowledge of such changes, in the main, is circumstantial, and statistics regarding them are almost wholly wanting. The cause or causes of such changes, moreover, are unknown. A change in the inclination of the earth's axis would be competent to account for changes in temperature, and therefore in rainfall.[3] Changes in inclination have certainly occurred, but their definite effects are not known. Changes in the level of a region are also capable of producing variations in temperature, and it is highly probable that elevation and depression have resulted in many of the climatic changes of which there is an unwritten record.[4]

Zones of Climate.—Zones or belts whose limits are bounded by lines of equal average temperature are called *isothermal* or climatic *zones*, and the lines bounding them *isothermal lines* or *isotherms*. A comparison of the map of the astronomical and the climatic zones shows that the correspondence of the two is only general. The former are fixed and their boundary lines are parallels of latitude. The latter change their positions with the apparent motion of the sun, behaving in this respect like the zones of winds and calms. In fact they are all governed by the same law



ISOTHERMS FOR JULY



ISOTHERMS FOR JANUARY

and arise from the same cause—the inclination and self-parallelism of the earth's axis.

In the southern hemisphere the isotherms range approximately with the parallels. What may be inferred from this concerning the uniformity of temperature with respect to latitude? In the northern hemisphere the isotherms are very irregular. In which direction do they bend in crossing the great highlands of the earth? Explain the cause of this. In the North Atlantic warm ocean currents and their drifts cause a deviation of the isotherms; explain how and why.

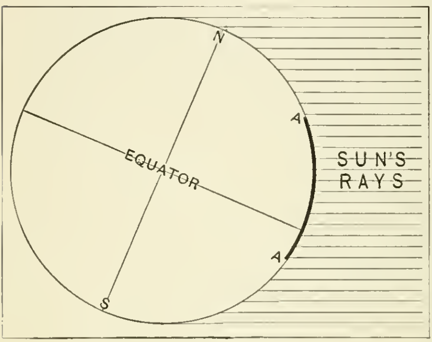
By what isotherms is the climatic torrid zone limited north and south? [5] Compare the position in January and July. In the spring and the fall its position corresponds roughly with that of the astronomical zone. The hottest areas are situated not on the equator, however, but north of it. In the African desert, Arabia, and the arid lands of the United States, the summer temperature is above 38° (100° F.) and during unusual hot spells it sometimes reaches 49° (120° F.).

The isothermal temperate zones are limited by the lines of 21° (70° F.) and 0° (32° F.). The summer limit of the northern zone extends high into the arctic regions. The winter limit on land approximates the fortieth parallel, but on the ocean it is much higher. In the Pacific it reaches to the sixtieth parallel; in the Atlantic, owing to the drift of the Gulf Stream it penetrates the polar latitudes.

Extremes of Climate. — The isotherm of highest temperature that completely girdles the earth is theoretically the thermal equator. Its temperature is probably between 27° and 30° (80° to 86° F.). There are several isolated regions having a considerably higher temperature, however. An extensive region in the Sahara has a mean temperature of about 29° (85° F.), and in Hindustan and

Africa there are others equally warm. In the American continent an oval-shaped region extending southward from the Gulf of California has about the same mean.

The regions of extreme cold are not in the vicinity of the geographical pole, but considerably south of it. In the American continent the area of extreme cold is near the Arctic Archipelago. In Eurasia it is a little to the eastward of the Lena River. In both regions the mean temperature is not higher than −17° (0° F.). At Werchojansk,[6] Siberia, the temperature ranges from −67° (−90° F.) to 32° (90° F.) a range of one hundred and eighty degrees—and probably the greatest on the earth.

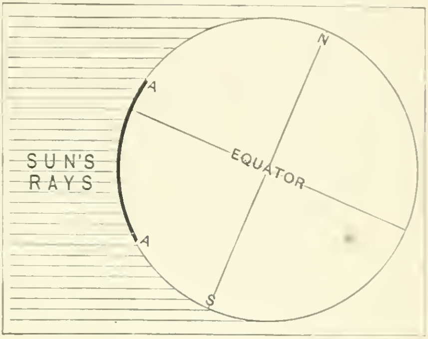


POSITION OF HEAT-RAYS IN JUNE

Changes of Season. — Because the earth's axis is inclined to the plane of its orbit, and remains parallel to itself while the earth revolves around the sun, it follows that the rays of the sun do not fall on a given place always at the same angle.

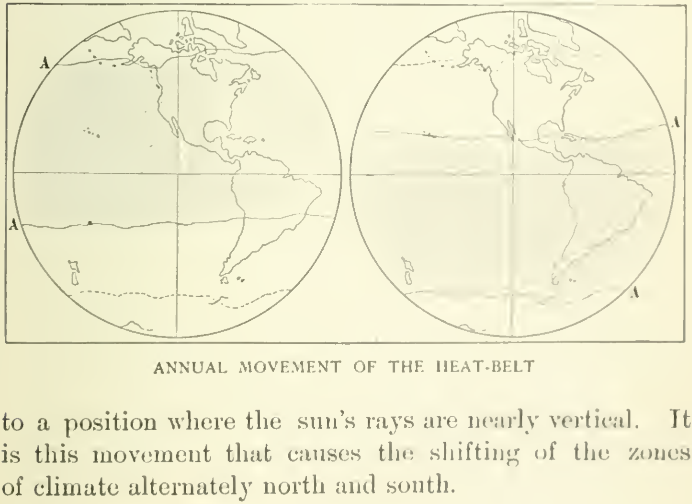
From the accompanying diagrams find the time at which the sun's rays are vertical at the tropic of Cancer. What is the season at this time in the northern hemisphere? Are the sun's rays direct or slanting in the southern hemisphere? What is the season there? What are the seasons when the sun's rays are vertical at the equator? On a piece of thin paper trace, with a pencil, the isothermal hot zone on the map for January, p. 292; cut it out along the lines, and place it in its proper position (*i.e.*, for January

on the map for July). The parts that overlap show the region where summer is continuous all the year. Compare this result with the diagram on this page. What parts are not covered by the heat-belt? When the heat-belt is far north what is the season in the Northern Hemisphere? in the Southern? From the oscillation of the heat-belt show how five zones of temperature result.



POSITION OF HEAT-RAYS IN DECEMBER

The inclination of the axis, together with its parallelism, as the earth revolves around the sun, bring the temperate zones, in turn,



ANNUAL MOVEMENT OF THE HEAT-BELT

to a position where the sun's rays are nearly vertical. It is this movement that causes the shifting of the zones of climate alternately north and south.

The alternation of the four seasons is realized mainly in the temperate zones. In the greater part of the western coast of North America the seasons are distinguished more by the distribution of rain than by variations in temperature. Practically there are two seasons—a rainy and a dry. Within the greater part of the torrid zone these are also about the only distinctions of season. In the frigid zones the distinctions of summer and winter are also those of day and night, each of which is six months in duration.

Deserts.—There are many extensive areas that have little or no rainfall. If the rainfall is so deficient that irrigation is necessary to produce crops the region is said to be *arid*; if it is too dry for food crops, it is generally considered a *desert region*. In many instances there is no sharply drawn line between fertile and arid lands, or between arid lands and deserts. For instance, all that part of the Mississippi basin east of the 97th meridian, or more strictly, the 2,000-foot contour—produces an abundance of food stuff. West of this contour, however, the climate becomes much drier, and beyond the 100th meridian or 2,500-foot contour, crops must depend mainly on irrigation.

Farther west, turf grass is replaced by scanty bunch grass, and beyond the crest of the eastern ranges of the Rocky Mountains the character of the country in places approaches that of a typical desert. In the northern part of the Basin Region, the cooler climate and the high ridges wring a small amount of water from the clouds, but in the south almost all vegetation disappears and the region is absolutely a desert. The same gradation is observed in the great African desert. Both north and south of the equatorial rain-belt, precipitation decreases little by little; fertile lands grade imperceptibly into arid belts, and the latter into deserts.

In the South American deserts the line, on the contrary, is pretty sharply drawn, and the same is true of the North American desert and the Sahara, if they are approached from the western side. In each case a high mountain-range forms a barrier to the rain winds, sharply dividing a fertile area from a desert.

Only a small part of the extensive desert areas is destitute of vegetation, and in such parts the finely pulverized rock waste, or "sand"[7] shifts hither and thither with the winds. It is in such regions that the fierce simoon and similar sand-storms prevail. The Colorado Desert, in south-eastern California, is an excellent example of the kind.

The climate of desert regions is marked by peculiarities and extremes. The winds are hot sand-blasts and whirls; the scanty rains come usually in the form of cloud-bursts; the temperature is one of frightful extremes; the relative humidity of the atmosphere rarely exceeds thirty per cent. of saturation. Notwithstanding all this, desert climate is wonderfully healthful.

Any fertile spot in a desert is called an *oasis*, and the latter is fertile because it is more or less abundantly supplied with water. On account of the presence of water, the oasis commonly yields a goodly supply of food-stuffs. Various causes contribute to the formation of oases. The underlying strata may be impervious to water, thereby preventing the latter from sinking deep into the soil, or there may be a mountain-crest that is sufficiently high to condense and precipitate more or less moisture. The water flowing down the slopes percolates through the fine rock waste at the bottom, much of it being held there in suspension. The oases of the North American deserts are of this character.

The distribution of deserts constitutes an interesting study. There are practically two zones, situated mainly

between the 20th and 50th parallels, north and south, that contain nearly all the desert and arid lands of the earth. In Eurasia and Africa a belt of desert stretches from the western coast almost through the continent.[8] In North America this belt is nearly 1,000 miles east and west. The deserts of the Southern Hemisphere are smaller in area only because of the smaller land area. In South America it lies at the eastern base of the Andes; in Africa, south of the Kongo water-shed; in Australia, it extends almost across the continent.

Various causes contribute to make arid and desert conditions; but in any case a desert is a desert, not because of any natural sterility of the soil, but because of the lack of moisture.[9] In some localities a high mountain-range that faces the sea-winds condenses all the moisture they contain and the opposite slope with its outlying area is therefore a desert. Explain why the Peruvian desert of South America is west of the Andes, and the desert of Argentina lies to the east of these ranges. Why is the region east of the Cascade and Sierra Nevada Ranges either arid or desert? What effects have the Himalaya Mountains on the rainfall of the region to the northward?

In other instances the desert conditions arise from other and more complex causes. Thus, between the 20th and 30th parallels there is a downward movement of atmospheric currents; explain why these may produce deficiency or absence of rainfall (p. 288). In some localities the winds blowing inland from the sea may enter localities having a temperature higher than that of the winds themselves, and in such instances their moisture is not condensed. The Australian and African deserts result mainly from one or the other, or both, of these causes. They are unfortunately situated with reference to latitude, and they also are lacking in high mountain-ranges.

QUESTIONS AND EXERCISES.—Referring to any good map, determine the climate of South America from the following suggestions, giving a reason for each statement: What are the conditions of temperature of the northern part? How do those of the southern part differ? In which part is temperature the basis of the seasons? In which is rainfall? From which direction do the rains of the northern part come? of the southern part? What is the effect of the Andes Mountains on the distribution of the rainfall? Give the location of the desert and arid regions. Note the effects of altitude on the climate of the highlands; of the lowlands. What evidence does the map give to show whether the rainfall of the Amazon basin is profuse or deficient? Explain why the basin of the Orinoco has two rainy and two dry seasons.

Compare the Asian and American deserts as to origin. How do the African deserts compare in this respect?

Prepare a summary of the climatic conditions of the state or county in which you live, noting especially any facts not ordinarily included in the general outlines of the subject. From the United States Weather Bureau obtain the following: highest temperature observed, lowest temperature observed, mean for each month, mean annual rainfall, mean for each month, number of rainy days for any year, general direction of the winds, other relevant facts.

COLLATERAL READING AND REFERENCE.

DAVIS.—Elements of Meteorology.
WALDO.—Elementary Meteorology.
GREELY.—American Weather.

NOTES

[1] To these may be added the effect of ocean currents. It is sometimes stated that the warmth of western Europe—the British Isles, especially—is due to the Gulf Stream, and that of the western United States to the influence of the Japan Current. So far as their temperature in general is concerned, such a statement is untenable. Ocean currents accomplish very potent results, however, but not because of their effects on climate. Thus, the warm drift of the Gulf Stream is carried by the Prevailing Westerlies into about every bay and cove of western

Europe; and as a result the harbors—even as far north as Hammerfest—are free from ice all the year.

[2] A noticeable and highly important difference between a maritime and a continental climate, is the *daily range* of temperature. In a maritime climate this rarely exceeds twenty degrees (F.), while in a few inland regions the fluctuations may be twice as great.

[3] That is, if the axis of the earth were to incline forty degrees, then the polar and the tropical circles would have a corresponding distance from the poles and from the equator, and the temperate zones each would be ten degrees in width, instead of forty-three. Or, if the longitude of perihelion were to change materially, the winters of the northern hemisphere might be longer by several days than the summers, thus causing the ice and snow to collect faster than it would melt, thereby in time causing far-reaching changes.

[4] The elevation of a region is thought to result in a lowering of its mean temperature, and the depression of its surface, it is believed, has an opposite effect. The surface of New York and the New England States was about 1,000 feet higher during the Glacial Epoch than at present.

[5] The mean *annual* temperature of a region reveals but little concerning its actual conditions of temperature. These can be studied only from monthly isotherms—that is, by comparing the monthly range of temperature and climate. For this reason, instead of a chart of annual isotherms, it has been deemed wiser to prepare two charts, one showing the isotherms for January, the other for July.

[6] Werchojansk (or Verkoyansk) is four hundred miles north of Yakutsk, Siberia. The two are in probably the coldest inhabited region in the world. The highest temperature taken under standard conditions—that is, shaded by a double roof with an air-space between, and exposed at a distance from any radiating surface—seems to have been recorded at Warglar, Algeria, where the mercury marked 127° F. In the Colorado Desert an unofficial temperature of 136° has been noted. In this case, however, it is doubtful if a properly exposed thermometer would have registered so much by ten or fifteen degrees. No temperature in this region recorded by the Weather Bureau has exceeded 122°, though there are several localities, such as Salton Lake and

Death Valley, where the temperature ranges higher than at any of the Weather Bureau stations. The author has repeatedly noted temperatures in the Colorado Desert varying from 130° to 145° registered by a thermometer exposed to the direct rays of the sun. The experience of General Greely, U.S.A., Chief Signal Officer, shows the range of human endurance. At Fort Conger, Lady Franklin Bay, he and his party experienced no intolerable discomforts with the temperature as low as — 66°. the same officer served in Arizona where the shade temperature was 119° and that of an unprotected thermometer 144°.

[7] The shifting soil of deserts is popularly regarded as sand. As a matter of fact it consists of about every kind of rock waste broken and pulverized by the impact it receives as it is blown about by the wind. Doubtless it contains more or less quartz, but in general, true quartz sand is rare. In the Colorado and Mojave Deserts the detritus passing for sand is broken felspathic rock ; in certain localities of the Arabian Desert it is a red, loamy soil.

[8] "The districts of the Sahara destitute of oases present a formidable aspect. The path which the feet of the camels have marked out in the immense solitude points in a straight line toward the spot which the caravan wishes to reach. Sometimes these faint footmarks are covered with wind-blown rock waste, and the travellers are obliged to consult the compass, the horizon, a distant sand-hill, a bush, a heap of camels' bones, or some other indications which the practised eye of the Tuareg alone can understand as the means by which the road is recognized. Vegetation is rare, and the only plants to be seen are the scrub, consisting mainly of thorny Mimosas ; in some sandy deserts there is a complete absence of all kinds of vegetation. The only animals to be found are scorpions, lizards, vipers, and ants. During the first few days of the journey a few indefatigable individuals of the fly tribe accompany the caravan, but they are soon killed by the heat ; even the flea itself will not venture into these dreadful regions. The intense radiation of the enormous white or red surface of the desert dazzles the eyes ; in this blinding light every object appears to be clothed with a sombre and preternatural tint. Occasionally the traveller, when sitting upon his camel, is seized with a kind of brain fever, which causes him to see the most fantastical objects in his delirium. Even those

who retain the entire possession of their faculties and clearness of vision are beset by distant mirages; palm-trees, groups of tents, shady mountains and sparkling cascades seem to dance before their eyes in misty vapor. When the wind blows hard, the traveller's body is beaten by grains of sand which penetrate even through his clothes and prick like needles. Stagnant pools or wells, dug with great labor in some hollow or other, from the sides of which oozes out a brackish moisture, point out each day the end of the stage. But often this unwholesome swamp, where they hoped to recruit their energies, is not to be found, and the people of the caravan must content themselves with the tainted water with which they filled thair flasks at the preceding stage. It is said that in times of great need travellers have been compelled to kill their dromedaries in order to quench their thirst in the nauseous liquid contained in the stomachs of these animals."—*Elisée Reclus.*

[9] In popular literature the climate of deserts is supposed to have baneful properties, and the expression "poisonous emanations" has a prominent place in many newspaper accounts. As a matter of fact, desert air is unsurpassed so far as salubrity is concerned. It is so free from the germs that produce or hasten disease, that meat will not putrefy and food will not ferment. Septicæmia, or "blood-poisoning," rarely if ever follows accidental wounds or surgical operations, and tuberculosis originating in such localities is unknown.

CHAPTER XVII

THE DISPERSAL OF LIFE

THERE are two lessons in nature that probably every human being of mature years has learned, namely—that the earth is full of organisms endowed with that mysterious force called *life*, and that the life-forms are grouped in kinds or *species*. Moreover, while the individuals of a species closely resemble one another, those of different species are commonly very unlike.

Almost every living body or *organism* passes through several stages or conditions.[1] It first appears in the form of a *germ* enclosed in an envelope called an *egg*, or perhaps, a seed. Under the action of heat, or moisture, or both heat and moisture, the egg or seed passes through various stages of development in which it gradually approaches its mature form—the condition that immediately precedes death. In general, the egg develops into a life-form, known as an animal, the seed into a plant. The egg may contain both food and moisture as well within its envelope; but the seed contains food only. The egg very easily loses its vitality or life principle; the seed may retain its vitality for months, or even years. The offspring of the egg almost always possesses the power of moving from place to place in one or another of its forms of life; the offspring of the seed, on the contrary, cannot move; it spends its life in the spot in which it developed into life.

The seed-form of the organism is remarkably adapted for transportation and dispersal. Commonly the seeds

are strong enough to resist not a little mechanical force. Those of some species will endure a temperature but little lower than that of boiling water; they will likewise endure the severest cold, and almost always they are enclosed in a water-tight case. The egg, on the other hand, will not endure extremes of temperature, nor will it survive the slightest injury. As a rule, both seeds and eggs float on

A BARRIER THAT CERTAIN SPECIES CANNOT PASS

water, and many kinds are so light that they are carried for miles in the air.

The stage of growth and development is a condition of the greatest danger to the existence of the organism. During this period it quickly and easily succumbs to the most trifling changes in its surroundings. At this time, too, it is apt to be the prey of higher organisms that kill

and devour it. Indeed, so great is the mortality during the period of development that, in many species, not more than one or two individuals in many thousand reach the state of maturity.[2]

The mature stage of the organism follows that of development. In this condition it has but one objective toward which all its energies tend, namely—the reproduction of its kind. This accomplished, sooner or later it dies; that is, the vital principle leaves it, and it is quickly resolved into the mineral elements—the "dust"—which gave it external form and structure. Not a few species have special means for the protection of their bodies, and nearly all possess special organs for the purpose of nutrition, and the higher species have organs of locomotion.

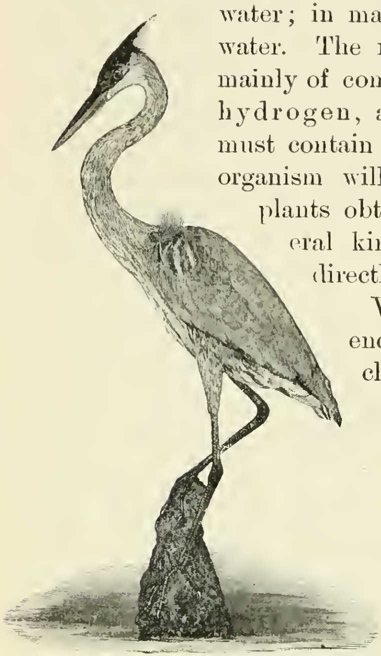
Laws of Structure.—Many laws are concerned in the growth, development, and reproduction of organic forms, but there are three that govern, directly or indirectly, every form of life. These are *heredity*, *nutrition*, and *variation*.

The law by virtue of which the germs of organisms develop and mature, each into a form of its own kind, is called heredity. The germ of a species always reproduces forms like those of the parents or ancestors. Acorns always produce oak-trees, animals beget each of its own kind, and the germ that in the human system produces disease, breeds nothing but disease of its own kind.[3]

A seed or an egg develops into an organism that becomes an ancestor of many thousand generations, aggregating millions of individuals. But in obedience to the law of heredity, the individuals of the last generation will not very greatly differ from their ancestor, nor will they differ from one another.

The process by which food, once within the body of an organism, is decomposed and then made a part of the structure of the organism is called nutrition, or feeding.

In obedience to this law, new tissue, that is, flesh, blood, bones, etc., is constantly being made, and older tissue, no longer useful, is cast off and destroyed. The number of substances required in nutrition is few. Nearly three-quarters of the weight of every organic being consists of water; in many instances 97 per cent. is water. The remaining part is composed mainly of compounds of carbon, nitrogen, hydrogen, and phosphorus. The food must contain all these substances or the organism will not mature. As a rule, plants obtain their food from the mineral kingdom, and animals, either directly or indirectly, from plants. Variation is the law in obedience to which organisms are changed, or change themselves, to meet the conditions necessary to their existence. Thus, under cultivation, the wild rose, no longer needing its multitude of stamens, develops them into petals. Under the conditions imposed by its environment, the almond has varied its development by taking the form of the peach and the nectarine.



VARIATION: ADAPTED TO ITS ENVIRONMENT

Birds that for long-continued generations have obtained their food from the water have become either swimmers or waders, and many species of those that scratch the ground to obtain food have gradually lost the power of extended flight. The great diversity observable in the various mem-

bers of the dog family is a familiar example of the effects of variation. The horse of present times has but one toe, but the ancestors of the species in Miocene times had three, and in Eocene times four toes on the fore feet.[1] The birds of early geological periods were much more reptilian in character than those of present times. Some of the reptiles, too, have lost their feet and are scarcely a remove from serpents.

Environment.—Variation of species is the result of food, temperature, and moisture. These are the conditions with which every organism has to battle for existence, and these determine all its habits. If the environment of a species changes, one of three things is pretty certain to take place: the species dies, it migrates, or else it survives with changed habits.

Thus, if in a given locality, the rainfall lessens materially, the turf grass quickly discovers it. In order to obtain the necessary moisture, an enormous development of rootlets takes place, and if this development does not procure the necessary amount of water, the turf grass gradually disappears. If a certain species requires an aggregate of ten inches of rain, distributed monthly, it will perish if the rainfall decreases to nine inches, or if there is a drought of more than thirty consecutive days. It will thrive and possibly extend its limits if the annual precipitation increases to twelve inches.

The fruit of the common gooseberry, cultivated in moist regions, has a smooth surface; but transplanted to arid regions and left to grow wild, the berry finally matures, covered with leathery spines. Cultivation, which is only another name for change of environment, has resulted in all the beautiful varieties of roses; it has produced the domesticated fruits from wild fruits; it has made the difference between the wild fowl and the domestic fowl of

the same species. Since the territory inhabited by a species is either enlarged or decreased by a change in food, temperature, and moisture, and since a change in any of these factors sooner or later results in variation, it is evident that the distribution and variation of species is governed mainly by geographic laws.

Causes that apparently are the most trivial are not infrequently attended by far-reaching consequences. For example, the mongoose was introduced into Jamaica in order to exterminate the cane-rat, then a menace to the sugar-planter. The mongoose did not lessen the number of cane-rats, but it exterminated one or two species of ground-bird, and with their disappearance there came such swarms of "cattle-ticks" and "grass-lice" that the existence of cattle-raising was threatened. The ground-birds had prevented any great increase of the insect species; but when the former were killed, the latter became an intolerable pest.

Animals and Plants.—Plants are lower in the scale of life than animals. A few species excepted, they have not the power of voluntary motion, and if they possess the power of sensation at all, the latter is of the very feeblest degree. They derive their nutrition mainly from the ground and the air, being able to transform mineral matter, such as water, lime, potash, carbon, etc., into plant tissue. With one or two exceptions, plants inhale carbon dioxide and exhale oxygen.

Plants exhibit only in the feeblest degree, if at all, the faculty of intelligence, and this is observed only in the way they seek their food. The roots of a plant will grow in the direction of water, and the flower will open with the light and close in the presence of darkness. No species is known that will pursue its prey or flee from an enemy. And the reason is obvious: the plant does not

exist at the expense of other life-forms; it merely transforms dead mineral matter into living matter, which is to become the food of higher forms. Nevertheless, the plant contains a vital force that causes it to live, grow, develop, and reproduce; and when this vital force is spent, the plant dies.

Animals—even the lowest species—are far more complex in organization than plants. The animal lives by the destruction of other forms of life, and therefore, in general, it must possess the powers of locomotion, prehension, or grasping, and also some means of defence. All animals possess intelligence, and some of the higher forms have the faculty of reason. No exact line of division, however, can be drawn between animals and plants.

Dispersal of Life.—The distribution of life over the globe is not a matter of chance; on the contrary, it exhibits a character that can result only by the operation of fixed laws. Moreover it must be examined from two sides, namely—the means possessed by animals and plants to disperse and, conversely, the barriers that operate to prevent dispersal.

The means of dispersal are many. All the higher species of animals possess the power of voluntary motion. Quadrupeds use their feet; birds fly; nearly all insects have at least one stage of development in which they possess wings; and fishes swim. Marine currents carry many species from the place of their birth to distant parts; and still other species are carried by floating matter, and in the crop of birds.

Seeds of plants are carried by the winds, by running waters, and in the crops of birds or in the digestive apparatus of animals. Commerce is responsible for the dispersal of most species used for food and many that are baneful to humanity.[5] In short, almost every organism

possesses means that, under ordinary circumstances would give it a far wider territory than it now possesses.

The natural or unrestricted migration of species presents an interesting aspect. In the temperate zones, as a rule, the dispersal has been from west to east; in the torrid zone it has generally been in the opposite direction. A moment's thought will suffice to show the reason for this law, namely—the direction of atmospheric and marine currents.

But there are many regions swept by marine currents in which the species they carry will not thrive, and quite as many traversed by winds that the winds never sow with seeds, and the soil never fertilizes. Such extraordinary effects cannot exist without causes, and these are the natural barriers to distribution.

Barriers.—The barriers to dispersal are even more potent than its agents. These may be reduced to two classes—*physiographic barriers* and *environment.* Chief among the former are the high mountain-ranges, oceans and deserts.

High mountain-ranges form a tolerably effective barrier to species not provided with means of locomotion, and the more extensive the highland the greater the difference of the species on the opposite sides. There are two reasons for this. In the first place, if the species are unprovided with means for migration they cannot cross it; in the second place, the conditions of climate on the opposite sides of high mountains are so different that the species might not survive, even if transported. The low temperature of the summit of the range might also be fatal.

The ocean and other wide expanses of water are effective barriers to land plants and animals. A few birds endowed with unusual powers of flight, have crossed the ocean; seeds and eggs have also made the passage; and not a few

species have been transported in vessels. But all these are accidental migrations, and even then the question of environment would still remain to be determined.

Deserts present the same difficulties. Few species are able to cross them; fewer still to remain in them, and the barrier once surmounted, there may be changed conditions which still forbid the intrusion of the species.

Environment has been considered in the light of a cause of variation, but it is far more potent as a barrier to

A DESERT BARRIER

the existence of a species. If a species requires a temperature not lower than 0° (32° F.), it will perish in a climate having a lower range. If it requires an annual rainfall of thirty inches, it will perish if the precipitation falls to twenty-nine inches; or if it requires a monthly distribution of rain, it will not survive any considerable number of droughts of more than thirty days.

Thus it is seen that every species demands certain conditions of food, temperature, and moisture. If these be of wide range the species will inhabit a wide geographical territory; if they be narrow in range, the limits of its existence will be correspondingly narrow. If the proportion, or degree, or quality change, even minutely, the species will vary; if they vary materially the species will perish.

THERE MAY BE ENEMIES THAT OPPOSE THE NEW-COMER

It sometimes occurs, however, that a species, once introduced and acclimated, is unable to maintain itself, or maintaining itself, is unable to spread to any extent over a region whose soil and climate are in every way adaptable. There are several reasons for this. The region may have been already pre-empted by other species that resist encroachment, or there may be enemies constantly at work seeking to exterminate the new-comer. As a re-

sult, there are some species capable of general dispersion that are confined to narrow limits, while others have spread themselves broadcast over both continents.

Thus, turf-grass is easily cultivated, but it has so many enemies that in a few localities only does it thrive in a wild state. The willow, on the contrary, spreads wherever it is introduced. The ostrich does not extend its territory, but the rabbit has become a pest in almost every part of the civilized world.

QUESTIONS AND EXERCISES.—Study the common thistle, the dandelion, or the winged maple, and show how these species may be spread.

In the temperate regions of North America in what general direction will those species depending on the winds for distribution be most apt to spread ?

Note any instance that has come under your personal observation in which plants have been carried into new territory by winds, by running streams, or by waves.

Note any instance within your knowledge in which either a natural feature or the activity of man has formed a barrier to the dispersion of a plant or an animal species.

What advantages have each of the following species for dispersal ? the camel, man, the burdock, the ant, the snake, the cotton plant.

The sting of the tsetse fly, an insect of Africa, is fatal to most cattle, but the offspring of those that survive, are immune from its attacks ; how will this fact affect the dispersal of cattle ?

COLLATERAL READING AND REFERENCE

SHALER.—Nature and Man in North America.

REDWAY.—The Arid Region of the United States.

NOTES

[1] Thus, among plants, these stages are the seed, the sprouting plant, and the mature, flowering stage. In animals they are the egg, the embryo, and the adult individual. Among the lower forms of life the changes are often far more complex. Most

insects pass through the forms of egg, larva, pupa, and imago, and in some species there are still other intermediate forms.

[2] As the enemies to a species increase, its fecundity is apt also to increase. Thus, the spawn of a female cod-fish aggregates several million eggs. If all these were to hatch and mature, the sea would hold but a few generations.

[3] Since the discovery of the fact that many diseases are due to the growth and development of minute organisms within the human body, the science of surgery and that of sanitation have been greatly aided. Septicæmia, variously known as "hospital fever" and "blood-poisoning," once the bane of every hospital, are now comparatively rare, and such diseases as small-pox, typhoid fever, and cholera may be readily quarantined and stamped out.

[4] Because of this struggle, that has been waging ever since life first appeared on the earth, only the individuals that can best adapt themselves to circumstances are able to survive. Variation is not always a gradual change in a whole species; it is quite as often a distinctive change in several individuals, and the transmitted change that marks the descendants.

[5] The Norwegian rat in America, the Colorado potato-beetle in Europe, and the English sparrow in the United States are examples. The California species of the phylloxera, an aphis or plant-louse infesting the grape-vine, was introduced into France and almost destroyed the vines of that country. The Russian thistle at one time threatened to overrun the wheat-fields of the Mississippi basin, and the strictest means are necessary to keep it under control. The gypsy moth, whose larvæ infests ripening fruit, has attacked the orchards of the New England States, and an expenditure of nearly a million dollars a year is necessary to keep its mischievous work in check.

CHAPTER XVIII

THE GEOGRAPHIC DISTRIBUTION OF PLANTS AND ANIMALS

Not far from 150,000 species of plant[1] and nearly as many of animal life are known to exist, and new species are discovered yearly. These are distributed in accordance with the laws noted in the previous chapter—that is, they live each in the locality best adapted to it. Plant life includes species that vary as widely in form and structure as the multitude of animal species.

Distribution of Plants.—The distribution[2] of vegetation may be considered in several aspects, namely—*abun-*

FORESTRY OF THE NORTHERN REGION OLD GROWTHS AND NEW

dance and *kind;* and these are best studied with reference to their regional position or else according to their altitude. The abundance of vegetation is governed mainly by the conditions of temperature and moisture. In a climate that is both warm and moist there is nearly always an abundance of vegetation. Because of this fact, plant life is most abundant in tropical lowlands, decreasing as the latitude and the altitude increase. In tropical regions it is profuse; in temperate climate, abundant; in cold regions, scanty.

With reference to the distribution of kind, two factors have been instrumental—environment and time. In the earlier geological ages certain species seem to have prevailed at certain centres, and from these they have spread in various directions. The area over which the species of a region may have spread is a question chiefly of time; the locus, one of environment. The vegetation of a given region is called its *flora*.

With respect to distribution the map on page 318 shows that five centres exist from which species have spread, or to which they are characteristic.[3] Name them.

The Northern Regions, Eurasian and American, include the greater part of the two continents north of the Tropic of Cancer and that part of Africa north of the Atlas Mountains. The two regions contain, as natives, a large number of the deciduous trees, grains, and fruits. The grains, maize excepted, and most of the fruits are characteristic of the Eurasian; the redwood, sequoias, sugar-cane, tobacco, and the yuccas to the American region. The two regions are separated by the Atlantic Ocean, and though the life-forms are not identical they are very similar.

The South American region embraces the territory south of the Tropic of Cancer, both mainland and insular. The mahogany, cinchona, india-rubber, and rosewood are among the chief species peculiar to the region.

The African or Ethiopian region includes all of Africa south of the Atlas Mountains and tropical Arabia. The baobab, oil-palm, euphorbias, bigonias, the coffee-tree, several heaths, and the geranium, are among the native plants peculiar to this region.

The Oriental Region includes the territory south of the Himalaya Mountains, and most of Malaysia. Among the principal characteristic species are the spices, the ebony, sandal-wood, and the melons.

The Australian Region comprises the continent of Australia and most of the islands east and north. The flora of this area is highly peculiar. The prevailing color of the vegetation is bluish-green and the leaves turn their edges to the sun. The eucalyptus or gum trees, the various tree-ferns, and the jarrah are peculiar to this region. In the north and east the Australian and Oriental regions overlap, and are marked by species characteristic to both. The Eucalyptus and the tree-fern have been introduced into California; the jarrah is much used in the manufacture of street paving-blocks.

The vertical distribution of species is determined by altitude. Thus at the base of the Himalayas and the Andes, the flora is tropical; higher up, the characteristic species of the temperate zones replace tropical plants; and at an altitude of twelve thousand feet, more or less, the vegetation is distinctly that of polar types.

Economic Plants.—Most forms of plant life have an important relation to mankind, and this is especially true of those used as food, as medicine, or in the arts. Chief among them are the grains and other grasses, tuberous plants, fruits, those yielding textiles, and those used for building timber.

The grasses probably extend over a wider area than any other family. Of these the sugar-cane and maize, or Indian

DISTRIBUTION OF ANIMALS

corn, are native to the American continent. All the others belong to the Old World, but have followed the march of mankind. The members of this family are the sole food of many hundred species of animals, and the seeds are consumed by every race and almost every tribe of mankind. The starch they contain gives them their chief value as a food-stuff.

Rice is confined chiefly to the marine marshes and swamp lands of tropical and sub-tropical regions, but there are one or more species of upland rice. Rice is the staple food of about one-half the people of the world. It is a notable fact, however, that in certain parts of China and India, wheat, little by little, is supplanting it. Pound for pound its nutrient value is not equal to that of wheat. Maize, or Indian corn, a native of the New World, is an important food-stuff in temperate and sub-tropical regions. It is the chief bread-stuff of the "mixed" and native races of the New World. In the United States and Canada it is used mainly as animal food, being converted into pork. Its use, both in the form of grain and meat, is largely increasing among the peoples of the Old World. It is also used in the manufacture of liquor.

Wheat is the bread-stuff of the civilized peoples of the temperate zones and, is the fuel of the activity and energy of the world. It is grown in the great plains of the temperate zones, but it thrives in sub-tropical and sub-polar regions. How do the topographic features of a plain affect the harvesting and transportation of wheat? How do they affect the evolution of harvesting machinery?

The world requires about 2,200,000,000 bushels of wheat each year, and the amount required is steadily increasing. Why? The annual crop is somewhat greater; in 1898 it was 2,700,000,000 bushels. It is estimated that the maximum crop possible is not far from twice this amount.

About one-fourth of the world's crop is produced in the United States.

Rye takes the place of wheat in many countries, and is one of the most important crops of Russia and Germany. A species of oat is native to the North American region, but the cultivated plant is an imported variety. It is a favorite food for horses. Barley, about the hardiest of the grains, is also much favored as a food for horses, but is employed mainly in the manufacture of malt liquors. Buckwheat [4] is not a wheat at all, but the nut or fruit contains a large percentage of starch ; hence it is much used as a food-stuff.

The canes include one of the chief sugar-producing plants. [5] They thrive best in tropical countries, and are extensively cultivated in the sub-tropical belts. In oriental countries the bamboo, a species of cane, is much used as a building material and in the arts.

The palms, next the grasses, probably yield the greatest variety of useful products. Cocoa-nuts, dates, sago, sugar, wine, and oil, are all derived from this family. So far as moisture is concerned, the palms have a wide range, but in respect to temperature they are restricted to warm regions. They occur in both hemispheres.

Tuberous plants are among the important food-producers. The potato, probably a native of Chile, has been carried to every part of the civilized world. It thrives best in temperate latitudes.

The yam [6] and its relative, the sweet potato, are indigenous to tropical America. The beet and the turnip are native to Europe. The former is now the principal source of sugar. The cultivated onion seems to have come from China, but a wild variety occurs in America. The manioc (or manihot) is native to tropical America, but has been transplanted to Asia and Africa.

The fruits are important, not only as delicacies,[7] but as foods. Among the foremost are the fig, the date, and the Corinth grape. They are native to the basin of the Mediterranean Sea, and the dried fruit is a necessary article of food in that region. The banana, native to tropical Asia, has become a recognized article of food in America.

The cultivated varieties of the apple, pear, peach, and plum are native to western Eurasia; the cherry, apricot, and almond to the eastern part of that continent. The melons and their near relatives, the gourds (including the pumpkin and squash), are also from Asia. The orange, lemon, and lime probably came from the southern slope of the Himalaya Mountains. So far as written history is concerned, the grape[8] has a greater antiquity than any other fruit, manna possibly excepted. It is found in a wild state in both hemispheres. The cranberry probably originated in the temperate zone of North America, migrating thence to Europe. The tomato is also native to America.

Most of the succulent and leguminous plants, such as the cabbage, lettuce, spinach, and peas, have followed the migrations of Europeans. The bean seems to have come from Egypt. Celery is undoubtedly of Eurasian origin; it is found in a wild state over a large part of the continent, but is extensively cultivated.

The beverage-yielding plants in one or more species are cultivated throughout the whole civilized world. Tea is sent from eastern and southeastern Asia to almost every other country. The best quality is grown on the chain of islands east of the mainland; it is also grown in the United States. Coffee is probably a native of Abyssinia, but is now cultivated mainly in the New World. It grows wild in the former region, and a similar species is native to the warm parts of California.

The cacao-tree yields cocoa-beans. The latter, dried

and browned, are used as an infusion; ground with its own fat or with lard it is the chocolate of commerce. It is native to tropical America. Mate (*mä-tā'*), or Paraguay tea, is the leaf of a species of holly native to South America. Its infusion is used all over that grand division.

The spices come nearly all from Southern Asia and the Malaysian archipelago. Of these none except pepper has been transplanted to any great distance from the place of their nativity. Capsicum, or red pepper (*chile colorado*), is native to tropical America. Nutmeg is a fruit, the covering of which is the mace of commerce; cinnamon is the dried inner bark of a species of laurel; cassia is a similar species growing in China and the New World; cloves are the dried buds of a tree native to the Molucca Islands and Southern India.

Medicinal plants are as widely dispersed as is the human race. The opium-poppy, native to tropical Asia, possibly to Egypt, has not migrated far from the place of its birth. The cinchona, a native of South America, but now cultivated in tropical Asia, yields quinine and a score of derivatives. The various members of the night-shade family [9] all yield powerful medicinal substances, among them nux vomica, strychnine, belladonna, and gelsemium; they are found in both continents.

Rhubarb and ginseng are native to China, but are now cultivated chiefly in the United States. The hemp that yields cannabis indica, or hasheesh, comes from southern Asia. Coca is native to the Andes. Cascara seems to be confined to tropical and sub-tropical America. Most medicines widely used are derived from plants found in tropical regions. Tobacco is native to America.

Plants used in the arts have followed man in his migrations. Cotton [10] is the furze attached to the seeds of the

cotton plant. Flax and hemp are obtained from the bark of flowering plants; both came from the Old World—probably from Africa—but four-fifths of the world's product is now grown in the United States. Jute and ramie are native to Asia, but are now cultivated in America. More valuable than either of these is pita, the fibre of the wild pineapple, native to America; and so also is henequen, or "sisal hemp," the fibre of the agave.

The forestry of the world is distributed with a remarkable degree of regularity. The pines and other conifers, oaks, elms, maples, willows, chestnuts, and beeches, occupy a belt between the 40th and 55th parallels that crosses both continents. The distribution of tropical forestry is not so regular, from the fact that South America has a flora peculiar to itself. The palm, banana, mahogany, bamboo, and representatives of the pines continue through both continents, however.

On both sides of the belts of forestry there are extensive treeless areas. In some instances the areas are treeless because they are deserts, but in others, such as the prairies and plains of Russia and the United States, there is a fertile soil and an adaptability of environment. In many instances there are no trees because the seeds have not been carried thither; because the rivers and the winds, flowing from regions that practically are deserts, carry no seeds into the regions toward which they flow.

In the United States forestry thrives best in a gravelly soil, but lives and increases in a sedentary, prairie soil. In the Champlain period that followed the Glacial epoch, the northern part of the United States was traversed by streams that bore the seeds of various species. Wherever the streams deposited gravel they also deposited seeds. Hence this region was sooner or later covered with trees. As a matter of fact, the timber-covered regions of the

northern United States are nearly identical with the area covered by stream gravel and till.

Distribution of Animals.—The animal life of a region constitutes its *fauna*. Of the various classes,[11] the mammals represent the highest types of life, both with respect to form and structure and also in the matter of intelligence. All the forms of animal life possess the attribute of instinct—the hereditary power of thought required in such actions as tend to preserve and extend life. The higher

THE PENGUIN

A type of Antarctic life

forms, in addition, have the powers of reason. These faculties have, doubtless, largely controlled the distribution of life.

In the dispersal of animal species the power of locomotion has given a wonderful development to both instinct and reason, and these have been controlled by the most powerful motive that exists in connection with animate life, namely—the sense of hunger.

As in the distribution of plants, there seem to be certain centres from which animal species have migrated. But the limits have been determined in a somewhat different way.

DISTRIBUTION OF VEGETATION

In the case of plants the territory of a flora is mainly governed by environment; in the case of animal life environment is an important matter, but the power of voluntary locomotion has been the leading factor. The limits of a fauna, therefore, are largely determined by its various physiographic barriers.

In the map, page 318, it is seen that the North American and Eurasian regions have a very broad extent, and are separated by marine barriers that are neither very wide nor impassable. In the south, the regions are surrounded by barriers that practically isolate them. For example, South America is separated from North America by the barriers of sea and climate. The African region has, in addition to these barriers, a high mountain range on its northern border; the same is true of India, south of the Himalayas; Australia is environed by the sea and also by peculiarities of climate.

From this it may be inferred that the faunas of the two northern regions are not greatly dissimilar. Such an inference is correct. In many instances the species are identical, and in others an order or a class has its representatives in both continents. The southern regions, however, are marked by strong contrasts.

The North American and Eurasian regions have in common many species of carnivorous, or flesh-eating animals. Various species of wolf and bear are widely dispersed through both regions, and the cat family is represented by the panther and several species of wildcat. Many furbearing animals—notably the lynx, otter, ermine, badger, and sable—are common to both regions, and so are species of the deer family and mountain sheep.

The grizzly bear, caribou, bison, musk-ox and black bear are peculiar to America; the first named is found only in the Rocky Mountain highlands. The reindeer,

camel,[12] buffalo, and nearly all domestic animals are native to the Old World, but have been transplanted to the American continent. The opossum, puma, bald eagle, humming-bird and wild turkey are native to the American region; the chamois, ibex, fallow-deer and aurochs are peculiar to the Old World.

The South American Region is distinguished by a profusion of animal life. The monkeys of this region are a

BORN OF THE SOUTH AMERICAN REGION SURVIVES IN THE OLD WORLD

species distinct from those of the Old World. The camel[13] of the Old World is here replaced by the alpaca, vicuña, llama, and guanaco—all distantly related to the camel. The last named, however, is probably native to the South American region.

The sloth, armadillo, ant-eater and peccary are peculiar to this region, and so are the numerous parroquets, and a

host of insect life. The condor is the nearest approach to the European vulture and the rhea to the ostrich.

The Ethiopian Region is conspicuous for the absence of the species most common elsewhere. On the other hand, the gorilla, lion, zebra, hippopotamus, giraffe, ostrich, five-toed elephant and many other characteristic species are found nowhere else. In but one other region is the pygmy, a dwarfed species of man, found.[14]

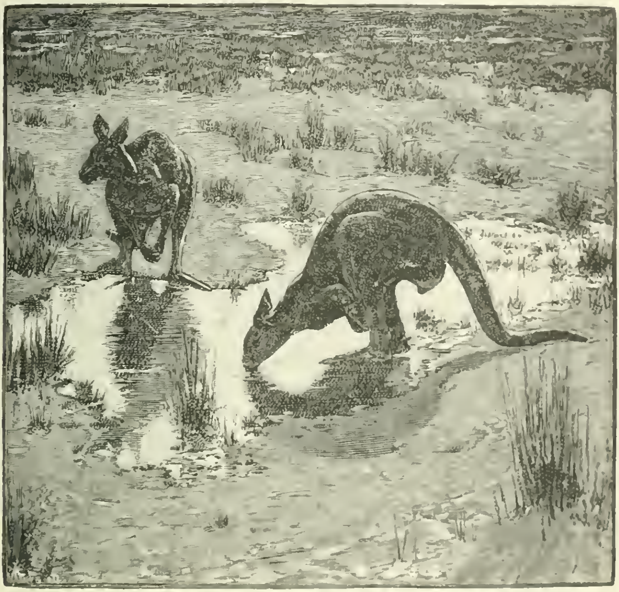
The Oriental Region is the birthplace of most of the domesticated animals. Among wild animals the tiger, mongoose, cobra, and three-toed elephant are peculiar to this region. The rhinoceros, jackal, and leopard are common to this region and that to the westward.

The Australian Region is marked by the most unusual types of life on the face of the earth. Almost all its life-forms are peculiar, and but few types found elsewhere occur in this continent. Many of the species are marsupials—that is, the female has a pouch or pocket in which the immature young are carried. Many others, such as the kangaroos, have enormously developed hinder legs. As a rule, Australian species are similar to those of a prior geological age.

The Bearing of Organic Life upon Physiography.—In the foregoing paragraphs the effects of physiographic forces upon life have been considered. The bearing of life and its energy upon physiographic forms are just as far-reaching and quite as important.

Life-forms have been and are now among the important agents in rock formation. Some of the limestone basins of the Mississippi Valley, all the infusorial earths, the various fringing reefs, the barrier reefs, the atolls, and the encircling reefs are the work of animal life. On even a more extended scale are the chalk formations of Western Europe, which are also the results of life.

In the broad areas of the tropical oceans the work of organic life is of still greater magnitude. The water of these regions is swarming with life, and the skeletons of the dead forms, together with other mineral constituents, are accumulating at the bottom. Wherever deep-sea



THE KANGAROO

A type of the Australian region

dredging has been carried on, these accumulations have been found.

But the secretion of the lime from the sea-water has had still another effect. After the lime and other mineral matter has been absorbed by the organism, the water is specifically lighter, and, as a result, the change in the density of the water has brought about a slow, but a none the less certain circulation of water.

Vegetable life also is responsible for extensive areas of rock formation. Under certain conditions, such as excessive saturation, the leaves, twigs, and stems of plants accumulate to considerable depths. If these accumulations be covered by overflowing sediment, either fluviatile or marine, the wood-fibre, after long-continued pressure and partial decomposition, is converted into coal.

In the United States more than 150,000 square miles of territory are underlain by coal measures, and in the various basins of Eurasia probably a greater area exists. The most extensive formations of this character are found in the later rocks of the Palæozoic age, but coal is not confined to any particular strata. Coal-making has been an incident of every geological age. Diamond, graphite, anthracite, bituminous coal, mineral pitch, petroleum, and natural gas are all the results of organic life.

In preventing general surface erosion, vegetation has also been an important factor. A surface covered with grass or foliage resists the action of rain and winds alike. Covered with vegetation a surface can withstand almost any amount of wind and rain, but denuded of vegetation, the surface is quickly scored by running water; gullies grow into ravines, and the latter deepen into impassable cañons.

It has been shown in another chapter that not only is vegetation capable of converting a moderately dry region into a swamp, but also that it may fill the swamp and afterward reconvert it into a dry region again. It may accomplish even more than this. A single species, such as the Russian thistle, may exterminate every other species of plant within a certain area.

As the native vegetation disappears so do the characteristic animals, and, sooner or later, the entire flora and fauna are changed. This changes also the character of

the soil; and as the topography of a region is due more or less to its characteristic vegetation, sooner or later this is changed.

The very lowest forms of vegetable life, such as the moulds, the bacilli, bacteria, and micrococci, perform an important office also. These forms, commonly known as disease-germs, may—and sometimes do—exterminate whole species, both of animals and plants. In company with the mosses and lichens they disintegrate and decompose the hardest rocks and crumble them into soil. In warm, moist regions exposed rock-cliffs and strata are much rarer than in arid regions. Fresh surfaces of rock once exposed are quickly covered with mosses, lichens, and the various protophytes. These, once established, require time only, either to completely disintegrate the rock, or else to cover its surface to a considerable depth.

The common earthworm plays an important part also. It thrives in moist earth, and a colony of these worms, once bred in a given locality, continues to inhabit it until the whole mass is changed to a rich, loamy soil, capable of supporting a dense vegetation. Thus it is seen that the lowly and often invisible forms of life become important factors in the physiography of a region.

QUESTIONS AND EXERCISES.—Make a list of the forest trees, shrubs, and other wild plants growing in the neighborhood in which you live.

Make a special study of any plant or "weed" regarded as useless or baneful. If you cannot obtain the information you require, send a specimen to the Department of Agriculture, Washington, D. C.

Follow the same directions with reference to the animal species, especially those injurious to vegetation, applying to the Department of Agriculture for information you cannot obtain elsewhere.

Enumerate the articles of food and table furniture used at dinner, and follow the route of each one from its native place to the table.

Mention the various uses to which maize or the corn plant is put — grain, cob, and stalk.

In what ways does the wheat crop affect the habitability of the United States?

Name some of the chief causes of the destruction of forestry. Note an instance in which the cultivation of the cotton plant has affected the history of a people.

Describe instances in which the distribution of animals or of plants has been effected by the agency of mankind.

COLLATERAL READING AND REFERENCE.

MILL.—Realm of Nature, pp. 302–320.

NOTES

[1] These are grouped in five sub-kingdoms. *The protophytes* are the lowest form of vegetable life. They consist each of a single cell or of groups of cells. In this sub-kingdom are included the yeast plant, and other similar substances known as ferments, the organisms that produce all the forms of "rotting" or putrefaction, and the host of bacilli, bacteria, and micrococci (commonly known as "microbes") that are productive of disease and various structural changes. *The Thallophytes* include the plants in which there is little or no distinction between leaf and stem, such as lichens and fungi. Nearly all the "sea-weeds" and the vegetable "moulds" belong to this sub-kingdom.

The bryophytes comprise the mosses and the liverworts. *The pteridophytes* rank a little higher. They include the club-mosses, horse-tail rushes, and true ferns. All the foregoing sub-kingdoms are flowerless; they reproduce by means of minute spores that are borne in receptacles on some protected part of the plant. The dust coming from a bursting puff-ball consists of spores, and these have the reproductive properties of seeds or eggs. *The phanerogams* include all the species of grasses, shrubs, flowering plants and forestry. Their growth, like that of certain lower forms, consists of two parts, the roots and the aërial portion. They reproduce by means of flowers and seeds.

[2] This term is used here because, unfortunately, it is almost universally employed in the science of geography. What really has occurred to spread the species is a migration or a dispersal.

[3] This classification by regions or centres is practically the same as that proposed by Professor Wallace, except that the names Eurasian, North American, and South American, are substituted for *palæarctic*, *nearctic*, and *neotropical*. This scheme has been adopted because it is based strictly upon geographic laws.

[4] Buckwheat, for convenience, is included in this list. The name is a corruption of "beech-wheat," on account of the resemblance of the kernel to that of the beech-tree. It is said to have been introduced into Europe by the Saracens, and in parts of Europe it bears the name Saracen wheat. It probably came from Manchuria.

[5] To these should be added the beet, which is now extensively cultivated for the purpose of sugar-manufacture. In tropical America certain agaves, near relatives to the grasses, are the source of not a little sugar.

[6] The yam is found also in the East Indies, and it is a disputed question whether or not the American species is a descendant of that of India.

[7] This fruit is commonly but incorrectly known as a currant. The latter is regarded as native to Eurasia, but wild species are certainly indigenous to western North America. The apple and the plum, said to be native to Eurasia, are also found wild in North America. The peach seems to have originated in Persia, from which the name is derived.

[8] The fox grape, a wild fruit growing in Canada and the New England States, was discovered and described by the Norse explorers who visited North America about A.D. 1000. The cultivated species of America are mainly imported; the Concord is an improved wild species of America.

[9] The potato, tomato, and tobacco are the most important American representatives of this family. The "jimson" (probably a corruption of *Jamestown*) and other species of the datura stramonium are found in all moist and warm regions of North America.

[10] Barbados and Sea-Island cotton are native to America.

[11] The classification of animals is somewhat more difficult than that of plants. The animal kingdom is divided into eight great branches or groups; these are again divided into classes and subdivided into the following orders:

Protozoans, the lowest forms of animal life, such as rhizopods, infusoria. *Porifera*, of which the sponges are the chief species.

Cœlenterates, of which the coral-polyps, jelly-fish, and sea-anemones are the best types. *Echinoderms*, represented by the star-fishes, sea-urchins. *Vermes*, or true worms. *Mollusks*, or shell-fish, such as the oysters, clams, limpets, snails, and slugs. *Arthropods*, including the types of lobsters, crabs, spiders, scorpions. *Vertebrates*, or animals having the back-bone.

Of these the first four inhabit the water ; the remainder include both land and water animals. The vertebrates comprise various classes of which the principal are *mammals*, or warm-blooded animals that suckle their young ; *birds*, mainly aërial in their habits ; *reptiles*, including snakes, lizards, and turtles ; *batrachians*, represented by frogs and toads, and *fishes*—all aquatic in their habits.

[12] The factors that have governed the dispersal of animal species cannot always be determined. It must be borne in mind that dispersal began in prior geological times, when the conditions of environment were often different from those of the present age. In the case of marine life, the limits to the territory of species are bounded mainly by the temperature of the water. The fauna of cold currents is materially different from that of warm waters. Deep sea species are wholly different from surface species also. The fish living at the bottom of the deeper parts of the sea are mainly sharks, several new species of which were discovered by the Prince of Monaco at a depth of two miles.

[13] The camel probably originated in America, but became extinct before the Glacial Epoch. In 1858 it was introduced into the Basin Region of the United States and a few head still survive in the Gila Desert of Arizona. The popular distinction between the camel and the dromedary is a very misleading and an incorrect one. The latter term (from a Greek word, to run,) first applied to a species remarkable for fleetness, afterward came to include any camel trained to fleetness of movement.

[14] There is some evidence of the existence of pygmies in Europe during the neolithic period, and recent discoveries in Switzerland strongly confirm the evidence. Dr. E. M. Aaron has called attention to the fact that the archæological records of Cozumel, an island east of Yucatan, bear evidence of the existence of a pygmy race. The ruins of the diminutive store-houses that are still found on the island, and the small human skulls lend credibility to the theory of pygmy existence in America.

CHAPTER XIX

MAN

Man, though at the head of animate creation so far as the development of reasoning powers are concerned, from a physiological stand-point is distinctly an animal, and is closely related to other vertebrates.[1] The skeleton of a man does not differ materially in structure from that of a monkey, a bear, a dog, or a bat; it does not differ very greatly from that of a whale, a lizard, or a bird; it closely resembles that of the gorilla.

With respect to nutrition the resemblance is still stronger. The digestive apparatus and the various processes by which food is converted into blood, bone, and flesh are the same in man as in other mammals. The food, moreover, is practically the same—water, grain, fruit, and the flesh of other animals. The organs by which the blood is circulated are the same, and the processes involved in breathing do not differ in any essential point in man and other mammals. In the structure of bone, muscle, and tendon,[2] and in the operation of special organs, such as nerves, intestines, lungs, and heart, the functions are practically identical.

The chief characteristic of mankind is the great development of the reasoning faculties. The power of reason is certainly common to some of the lower animals—possibly to all species. In man, however, this faculty is enormously developed in comparison with other animals. Moreover, the power of reasoning abstractly seems to be possessed by no other species of life.

The classification of mankind into races and families, however, is one of such great difficulty that no two ethnographers are in full agreement.[3] Color of skin, texture of hair, and language have been each made the basis of classification, but each system, when closely followed, leads to confusing difficulties.

The Black Peoples.—The people of this type are characterized by black skin, kinky or woolly hair, and thick lips. The Negroes are the best known people of the type. This race is native to Central Africa, but has been acclimated in America, numbering there about ten or twelve millions. The Bantus are the finest specimens of the black type, and in their native region are approaching civilization. They are distinguished by a color of skin that in some cases is distinctly bronze rather than black. Their features are finer, and the lips thinner than those of the Negro.

THE BLACK TYPE: A SAVAGE

The Australasians inhabit the continent of Australia and the near islands. They are tall and slender, have straight hair, and represent the lowest degree of civilization. The Melanesians are native to New Guinea and the chain of islands to the southeast. There are also tribes in various parts of the Philippine Islands. The Melanesians and Australasians are also called "Negroids." They are savages, warlike and ferocious. Cannibalism is almost universally practised among them, but is not confined to the black races.

The black type of mankind is best adapted to a warm climate, and the various races are free from the malarial fevers and other baneful climatic influences that are so fatal to white peoples. In tropical regions the Negro races are by far the most enduring peoples. The religion of almost all the people of this type is fetich or obeah worship.

The Yellow Peoples.—The yellow or Turanic peoples are probably native to Asia somewhere north of the Himalaya Mountains. The type is characterized by coarse and straight black hair, high cheek-bones, and

AMERICAN INDIANS

yellow or yellowish-brown skins. In some instances, as the Chinese, the eyes are set at a peculiar angle, giving rise to the term "almond-eyed."

Chief among yellow peoples[1] are the Chinese, Burmese, Anamese, and Siamese. The civilization of the Chinese is an old one and highly elaborated. In religion they are nominally Buddhists, but in fact they are given chiefly to ancestor-worship. The Tibetans represent the best examples of the race. The Burmese, Anamese, and Siamese are pure Buddhists. The Mongols of western and northern Asia, especially the high plateaus, are a race of nomadic

horsemen, courageous and intelligent, but only a remove from the savage state. In religion they are Mohammedans. The offshoots of this race that have settled in Europe—the Turks, Huns, Laps, and Finns—have reached a high degree of civilization.

The Japanese are probably a mixed race—Mongol and Malay, with which possibly there has been absorbed a still older race, native to the islands. Intellectually the Japanese are at the head of the race which they represent, and within forty years they have developed a civilization comparing favorably with that of European nations.

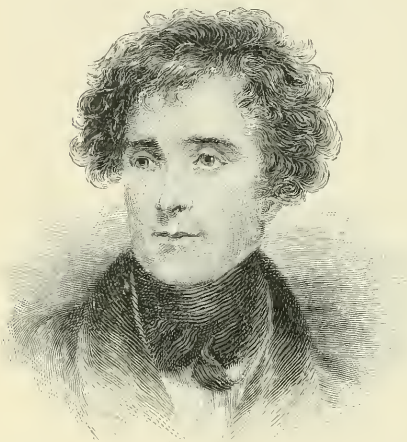
The Malays, or brown race, inhabit southeastern Asia, and the islands to the eastward. In their present state most of them are savage, but they seem to have the capabilities of an advanced civilization—a fact apparent in the Japanese, Javanese, and Hawaiians. The Maoris of New Zealand are an excellent type of Malay. The Hovas[5] of Madagascar, belong to this race. Most of the native peoples of the Philippine Islands are Malays. The Tagals have reached a condition of civilization; the Visayas and Maccabeles are but little inferior; the Moros are savages.

The American "Indians," for the greater part characterized by a brown color,[6] are native to the American continent. At the time of the discovery of America several tribes, such as the Aztecs and Peruvians, were emerging from a state of barbarism into one of civilization.[7] They were gradually absorbed by their conquerors.

In South America and Mexico the Indians have become a mixed race. For the greater part, this has resulted from inter-marriage with the Latin races—especially the Portuguese and Spanish. In North America, on the contrary, where the associations between Indians and Teutonic peoples have always been marked by bitter hatred, the Indian blood is still pure.


ARCTIC OCEAN
Greenland
ESKIMOS
ESKIMOS
INDIANS
GERMANIC
INDIANS
LATIN
INDIANS
Hawaiian Is.
West Indies
ATLANTIC OCEAN
PACIFIC OCEAN
MALAY
INDIANS
LATIN (SPANISH)
LATIN (PORTUGUESE)
INCAS
Equator
Tropic of Capricorn
Iceland
Arctic Circle
British Isles
GERMANIC
LATIN
SLAVONIC
FINNS
MAGYARS
CAUCASIANS
BERBERS
SEMITIC
TUAREGS
HAMITIC
ARABS
NEGRO
BANTUS
Madagascar
INDIAN OCEAN
HINDU
TIBETANS
MONGOLIANS
CHINESE
JAPANESE
Tropic of Cancer
PACIFIC OCEAN
Philippine Is.
Borneo
NEGROID
PAPUANS
GERMANIC
Tasmania
New Zealand
Races of Man.
White Yellow Black Am. Ind. Malay
The Density of Population
is shown by Strength of Color.
THE M. N. CO.
RACES OF MAN

The Eskimos, one of the most interesting divisions of the yellow type, are confined to the north circumpolar regions. They seem to be related to some one or other of the Mongol races, but the relation is distant. They are short in stature, averaging less than five feet in height. They are intelligent and highly susceptible to civilization. This fact is unusual, inasmuch as their habitations are mud and stone huts; their occupation, fishing; and their food, raw blubber and fish.



WHITE TYPE: LATIN

The White Peoples.—This race comprises two great divisions, each subdivided into various families. These divisions, moreover, represent language and relation, rather than structure. The color of the skin varies from light blonde to swarthy, closely approximating black among certain peoples. Intellectually, it is the dominating type of mankind.

The Aryan division is by far the most widely spread and numerous of the type. In Asia, it includes the Hindus, the Persians and most other dwellers in the Iran plateau. In Europe, it includes almost the entire population, the Turks, Huns, Lapps, Finns and Semitic peoples excepted. In the American continent, to which its peoples have migrated, it embraces about one hundred millions of souls, mainly of the Teutonic family.

The Teutonic, Latin, Sclavonic, and Keltic families of this race now constitute the leading, most intellectual, and most powerful nations in the world. These families occupy most of Europe and the greater part of North America. Here the peoples of the various families are confusedly mixed by intermarriage. In South America they have intermarried with the native races.

The Semitic family comprises the Hebrews, Moors, Arabs, and Abyssinians.[8] The Assyrians and the Phœnicians were also of this race, but they have been absorbed, or dispersed by conquest. The Hebrews or Jews are the only surviving remnant of this race now holding a position of any importance. For about four thousand years, in spite of fearful odds against them, they have held a commanding position.

WHITE TYPE. A REPRESENTATIVE OF THE HIGHEST CIVILIZATION

Springing from a family whose native place was not far from Syria, the Jews became a nation of considerable importance. Because of their steadfastness to their religion, neither slavery nor conquest has exterminated them. Diffused over the earth, they are numerically about as strong as ever they were, and their religion and ceremonial rites are as marked to-day as they were four thousand years ago.

Pygmies.—Scattered over a considerable area of Africa are peoples having no ethnographic connection or relation

to any of the foregoing families. These are the pygmies.[9] So far as the color of the skin is concerned, there are two classes of this people—one having a light brown skin, the other being almost black.

Of the various pygmy tribes the best known are the Akka, Wambutti, and Batua of central Africa, and the Bushmen of the southern part. All individuals are characterized by a heavy growth of rusty, red-brown hair upon the bodies, prognathic jaws and retreating foreheads. The average stature of the Bushmen is about five feet; of the other tribes about four and one-half feet. The Akka are characterized by mis-shapen bodies, long, skinny fingers, and withered legs. The Negroids of the Philippine Islands are sometimes classed among the pygmies.

A PYGMY

Nearly all the pygmy tribes have learned the use of fire, but, as a rule, they eat their food raw. Although they have a very low place in the human scale, they display considerable intelligence. The Wambutti are ingenious in devising nets and traps for securing game, and they seem capable of a low form of civilization. The pygmies are rarely at war either with the other African tribes or with one another.

Antiquity of Man.—The written history of man does

not extend backward more than six thousand years before the Christian era, and of this period the first half, as recorded in Holy Scripture, contains data concerning but one or two families and their descendants. Geological history goes back to a period of greater antiquity, but unfortunately gives no clew whereby the age of man can be computed in years. Written history did not begin until man had reached a comparatively high state of civilization, but geological history antedates this period, and discovers man living practically in a wild state, as a hunter and a dweller in caves.


YELLOW TYPE JAPANESE.

If man preceded the Glacial epoch, about every trace of the species disappeared. With a few exceptions, upon which doubt has been thrown, the oldest traces of mankind are found just above the unsorted drift of the Glacial epoch, and below that of the river gravels of Champlain times. Above the glacial drift, however, there can be no doubt of the existence of the species.[10]

Both in Europe and America the bones of man, associated with those of the cave-dwelling animals he hunted, have been abundantly found. With these have been found also implements of the chase, ornaments, charred pieces of bone, and in one instance a rude drawing of an extinct species of elephant, scratched on ivory.[11]

From the time of the earliest geological history of the species, there is observable one feature that distinguishes

EMERGING FROM A SAVAGE STATE

mankind from brute creation, namely—rapid intellectual development. Primitive man had learned the use of fire, and this in itself was to give him supremacy over all other animate nature. He had also acquired the use of tools, and these were a great increase of power. The earliest race of people employed hammers or axes of rough stone. The

next step seems to have been the making of polished stone axes, knives, arrow-heads, etc. When, however, the primitive man applied fire to the shaping of his tools and implements made of metal, his civilization was assured, and his power became supreme.

At first the metal employed was a crude alloy now known as bronze. At a later period, however, iron was substituted for the alloy. Some of these implements were of an ornamental character, but in the main they were either tools or weapons. With the increased power afforded by these tools the people who used them pass out of the state of savagery and emerge into that of civilization.

Migrations of Mankind.—The history of mankind is the history of successive migrations that have been going on for more than four thousand years. From the earliest times people have associated in families, families have grown into clans, and clans into tribes. When a region has been sparsely settled, association and government have commonly been of the patriarchal kind, the oldest one of the family or clan being the leader.

In cases, however, where there has been a common enemy, the plan of association has often been communal as well as tribal. Thus while the families described in the earlier history of the Old Testament observed a patriarchal rule, in later times, the plan of government became communal and afterward national. The same evolution had began in the case of the aboriginal Americans. Families had grown into clans and tribes, and among the Aztecs and Peruvians, tribal association had grown into communal government and was fast emerging into civilization.

But there have always been limits to the growth of a people. They may be exterminated by a stronger race; they may be dispossessed by a stronger people or be absorbed by them; or they may find the region too much

overstocked, and incapable of supporting so great a population. In any case, unless the people is exterminated or absorbed, migration is the only remedy.

Thus, tribes of the Tartar[12] race, known in history as the Huns, migrated from the plateaus of Asia and overran a large part of Europe. On their way they drove the

THE HABITATIONS OF A BARBAROUS PEOPLE

eastern Goths from their lands, and the latter, in turn, overwhelmed Italy and Spain. The Lombards, a Teutonic people, migrated from the shores of the Baltic to the Adriatic Sea. The Vandals swept over western Europe, leaving behind a trail of fire and blood. They devastated Spain, crossed to Africa, and established an empire on the site of Carthage. About one hundred years later they were exterminated by a Roman army. Under the teachings of Islam,

the Arabs (or Saracens) devastated the north of Africa, entered Spain and penetrated France. They founded a Moorish empire, but were afterward driven from Europe.

The foregoing are but a few of the movements of population that occurred in the short space of three centuries, and in the smallest natural division of land. History takes no note of similar changes that must have been going on in other parts of the world at the same time.

The records of unwritten history furnish many instances of the dispersions of peoples that must have taken place on a considerably greater scale. In some instances the migration was a systematic movement that practically was the advance of an army; in other instances it was a gradual extension of limits.

The migration of the Aryan race is an illustration of systematic dispersion. From some part of Eurasia the various families of this race wandered westward until they occupied all Europe. From Europe, moving still westward, they have subjugated the American continent, and even now the advance guard is knocking at the doors of Asia, after nearly completing the circuit of the world. There can be but one explanation of such a wonderful dispersion. It is the struggle for existence—the energy put forth to appease the cravings of hunger.

Man's Relation to Physiography.—The influence of man as a geographic agent is often overlooked and the far-reaching consequences are seldom appreciated. These effects may be classified as interference with the ordinary course of natural events, in respect to the surface of the land, with respect to climate, with reference to drainage, and in the dispersion of life.

The surface of the land has been modified by man in many ways. Of these the most important is the destruction of forestry. In both Europe and the United States

a very large part of the surface once forest-clad is now bare. By various artifices, running streams have been made to cover enormous surfaces with fluviatile deposits, and by the same process immense volumes of soil have been removed from one place to be transported to another and more available locality.

Piers and sea-walls have been built in such places as to extend shores to a considerable distance seaward. Thus, nearly one-third the area of the Netherlands has been reclaimed from the ocean; Venice has become a city of the mainland; and considerable areas of Chicago, New York, Boston, and San Francisco are built upon land that has been made by the industries of man.

The various highways, roads, railways, and canals, together with the levelling and filling that accompany the growth of cities and towns, form a permanent record of mankind. More than this even, is the surface covered by the rubbish carted from cities and spread here and there. It is estimated that the surface of Jerusalem has been buried many feet by the accumulating rubbish. In places, the city of Rome has been filled forty feet deep, and the same result has obtained in the vicinity of other cities.

By the diversion of drainage, swamps have been changed to dry land and their flora entirely replaced by other species. By canals and ditches, lakes have been drained and the lake basins given up to cultivation. By systems of levees and jetties, river-basins have been limited in area, and the area of sediment-depositing has been changed from one place to another.

Perhaps the most important changes that have resulted from the hand of man, however, are connected with the dispersal of life. Through his agency various species have been transported to all habitable parts of the earth; many species have become extinct, and the habits of still

others have been greatly changed. It requires only a brief geological period until the interference of man shall prove to be one of the most important of physiographic agents.

QUESTIONS AND EXERCISES.—Why will not the ordinary laws concerning the distribution of life apply to the dispersal of man?

Make a list, as complete as you can, of the various races and families now in the United States; from what part of the world did each come?

Name the advantages possessed by man over other species in overcoming the restrictions imposed by his environment. In what ways can he override such barriers as the sea, deserts, polar regions, and regions not habitable by other species?

How, and in what instances, has the discovery of gold affected the migration and dispersal of man?

Mention one or more instances in which this dispersal has been caused by an enemy.

COLLATERAL READING AND REFERENCE.

SHALER.—Nature and Man in North America.

MILL.—Realm of Nature, pp. 320–327.

MARSH.—The Earth as Modified by Human Action.

MINDELEFF.—Migrations of the Cliff Dwellers—*Bureau of Ethnology.*

DENIKER.—Races of Man, pp. 456–466.

NOTES

[1] Man is the only animal that habitually walks erect—that is, with the spinal column perpendicular to the plane of the feet.

[2] Healthy lung tissue, or that of the heart, the liver, the muscle are so closely alike in structure that a section from one animal serves perfectly as an illustration of the corresponding tissue of another.

[3] The futility of even the most carefully made classification is apparent when one considers the various interbreeding and amalgamation of races. For instance, the Romanic family embraces the five peoples enumerated in the foregoing table. But the

Romans were a mixture of Latins, Sabellians, and Etrurians, only one element of which is known certainly to be of Aryan descent. An infusion of Greek blood developed the fighting powers of the mixed race, and led to the conquest of the greater part of Europe. When the Western Empire had broken into fragments, the Latin language was finally modified by the different races who had adapted it, to Spanish, French, Portuguese, and Italian. But the Spanish were a mixture of Keltic and Iberian blood, the French were of Keltic and Gallic stock, and the Portuguese of Keltic, Gallic, and Iberian descent. Now a certain amount of Roman blood was intermixed with all these peoples, but in hardly an instance is there physically a race characteristic among them that is distinctively Roman. A similar mixture took place in the case of the English people. Although popularly known as Anglo-Saxons, the amalgamation is far more extensive ; it includes Angles, Saxons, Jutes, and Danes, together with a general mixture of Gothic blood. To this must also be added the infusion of Latin blood that came with the Norman Conquest.

[4] The Caucasians, a people south of the Caucasus Mountains, who are usually taken as the best type of the white races, belong to this family.

[5] Among the various races of Madagascar the Hovas are foremost, and in respect to intellectual development are not surpassed by any other African peoples.

[6] In spite of the free use of red pigments which the Indians were accustomed to use on their faces, a prevailing characteristic of the race is the color of the skin, which inclines to a copper-red. This feature is not true of the Pacific-coast Indians, however, all of whom are distinguished by swarthy or black-brown skins. The term "red men" is one that has been not wisely chosen.

[7] Among the pre-historic peoples of the continent none have excited more interest than the mound-builders and the cliff-dwellers. According to popular belief both were a distinct race of people whom the Indians exterminated. As a matter of fact, they were nothing more nor less than Indians. At the time of the discovery of America by Columbus, some of the native Americans, the Aztecs for instance, were in early stages of civilization. Most of them, however, were still in the stone age, and were therefore in a state not higher than barbarism. Still others

were in an intermediate state, and these had begun to forsake the wickiup or tepe for houses constructed upon architectural principles. The tribes who had reached this development were responsible for mound-building. The Senecas and Mohawks had already begun to build the famous long houses; the Shawnees, Cherokees, and Delawares had not reached quite so high a plane, and were still mound-builders. The cliff-dwellers were emerging from barbarism and built their pueblos of selected stone. For better protection they commonly built them on high mesas, on cliff-terraces, or even in caves. The Aztecs, to whom the Zuñis and Moquis are the nearest living approach, were on a much higher plane and seem to have emerged from barbarism at the time of the conquest of Mexico.

[8] Some of the Abyssinians are certainly Semitic, but for the greater part these are comprised in the nomadic Arabs who have gradually extended their limits to a large part of Africa. The earlier inhabitants are Aryans, however.

[9] The existence of pygmy tribes is mentioned by Herodotus, Pomponius Mela, Aristotle and others, but as recently as thirty years ago it was believed that the accounts of them were mythical. In 1865 the famous African traveller, Paul Du Chaillu, discovered the Obongo tribe, being the first one in modern times to do so. His accounts were flatly contradicted in Europe, but a few years later they were confirmed by Père des Avanchers, an Abyssinian missionary. In 1871, another tribe, the Akka, were discovered by Dr. Schweinfurth.

[10] It is by no means certain that man did not precede the Glacial epoch. A skull found by Professor Whitney among Pliocene deposits and various other relics found among the auriferous gravels of California, indicate a much greater age than post-glacial existence. As a matter of fact, the search for prehistoric and fossil man has been neither extended nor systematic. Practically no investigations have been made among the Miocene deposits of Central and Southern Asia, where of all places systematic researches should be made.

[11] This piece is now in the British Museum. Of its origin and antiquity there is no doubt.

[12] The Tartars overran Russia, Turkey, and Hindustan. They are among the most intelligent of the Turanic peoples.

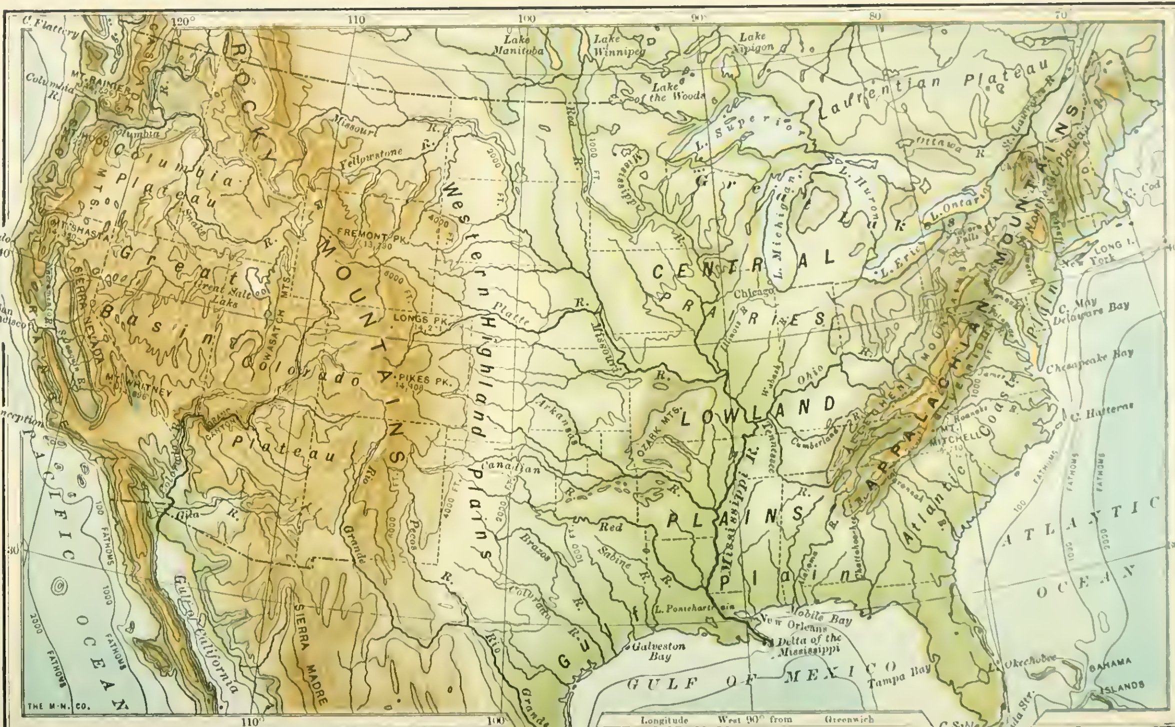
CHAPTER XX

THE INDUSTRIAL REGIONS OF THE UNITED STATES

THE main body of the United States extends from the colder part of the Temperate Zone to the Torrid Zone, the isotherm forming the northern boundary of the latter, crossing the southern parts of Florida, Texas, and the lower part of the basin of the Colorado River. This part of the United States is divided naturally into physiographic regions that have fairly well-defined boundaries; and because of their features of surface and climate, each region has become a great centre of industries that are peculiar to it.

The boundaries of these regions are both topographic and climatic, and the regions themselves differ from one another in either climate or topography, or in both. Roughly speaking, the groups of States commonly recognized do not differ very greatly from the industrial groups that result from diverse conditions of climate and topography.

The following are the principal physiographic and industrial regions: The *New England Plateau*, including the eastern part of New York; the *Middle Atlantic States*, including the Atlantic Coast Plain and the middle and southern Appalachian Highlands; the *Great Central Plain*, including the regions commonly known as the Northern States and the Southern States; the *Western Highlands*, including the region west of the 2,000-foot contour, the Rocky Mountains, the Columbia Plateau, the Colorado

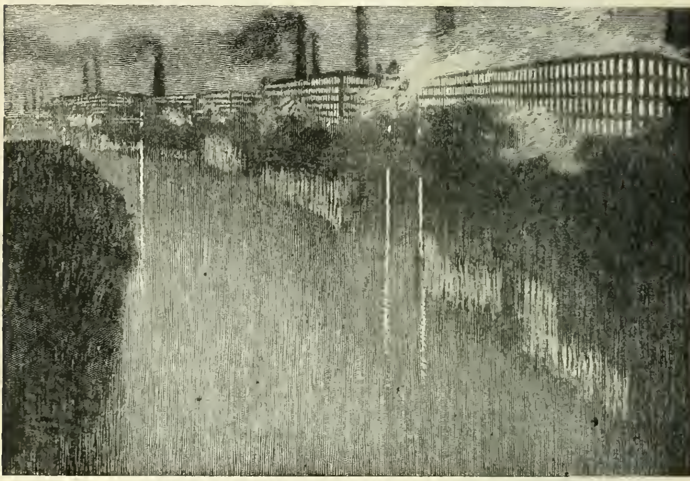


Highlands above 2000 feet in Buff
and Lowlands in Green.

The depths of the Oceans are shown
[illegible] Tints.

Plateau, the Basin, the Sierra Nevada and Cascade Mountains; and the *Pacific Coast Region.* Make a list of these, grouping each subdivision under its principal division.

The New England Plateau.—This region embraces the northern Appalachian folds, with here and there areas that belong to the Laurentian highlands. During the glacial epoch this region was greatly worn. The Appalachian folds in places were almost obliterated, and the



THE RUGGED SURFACE AFFORDS WATER-POWER

Green, White, Adirondack, and Catskill Mountains are the principal remnants. Here and there are isolated "monadnocks," most of which are bosses of volcanic rock which were able to withstand the erosion and corrosion that resulted from the work of the ice age. Granitic rocks prevail, and their rounded surfaces are generally smooth and polished.

As a result of the glacial epoch the surface of the New England Plateau is very rugged, the only level regions

being the river flood plains and the old lake basins whose waters have disappeared. Many lakes still remain, however, and these, a few coast lagoons excepted, have very strongly the character of glacial lakes and tarns. Name six of the largest. The slope is somewhat abrupt and, as a result, the rivers flow in "reaches"; that is, stretches of slack water alternate with rapids and falls.

The coast region is equally peculiar, and, inasmuch as it has been submerged or "drowned" in comparatively re-

A HARBOR COAST

cent geological times, the sea now intrudes upon the glaciated regions, making the whole shore-line one of fjords, like those of Norway. Practically all the good harbors of the Atlantic coast of the United States are confined to this region and, as a result, about four-fifths of the foreign commerce of the country goes in and out of its ports.

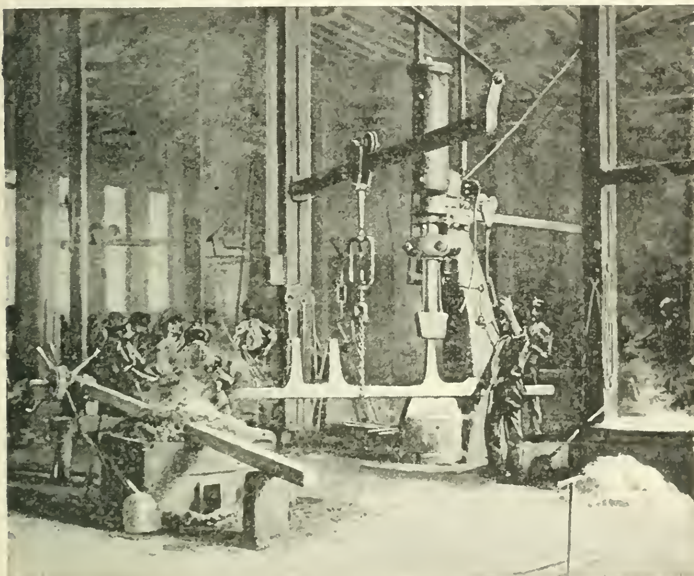
The rugged surface may be classified as uplands and valley lands. The uplands are characterized by thin and innutritious soil. The surface is diversified by drumlins, eskers, and granite hog backs; and much of it is strewn with erratic bowlders. The uplands are not capable of supporting a dense population,[1] and in the past half century there has been no material progress in agricultural pursuits; on the contrary, farming lands have depreciated in value. About all the industrial gains have been associated with manufacture. How does the surface affect this industry? The farming is confined to the lowland valleys and restricted to garden and dairy products. This region is celebrated for the manufactures that require a high degree of intellectual and mechanical skill,[2] and these have resulted from the conditions that have afforded the abundant water-power. The manufactures form a large proportion of the nation's foreign exports. The sewing-machines, bicycles, clocks, and firearms made in the mills and factories of this region are shipped to almost every part of the world; the cotton cloth is used by about every race of people.

The Middle Atlantic States.—This region includes the principal part of the Atlantic Coast Plain, together with the middle and southern Appalachians. The lower part of the Coast Plain consists of a belt of swamp lands bordered by sandy pine-barrens. Beyond these there is a belt of Piedmont lands—the foot-hills of the Appalachian Mountains. The rivers flow into estuaries that reach usually to the foot-hills and are generally navigable to this line—the "Fall Line." From any good map make a list of cities along the Fall Line.

The soil of this region is not well adapted either to cotton or wheat, although small quantities of both are grown. The chief crops are early fruit and garden stuffs, and these

find a ready market in the great cities of the manufacturing region. Cotton and tobacco are important crops in the southern part of the Piedmont lands; and on account of the water-power, now tardily developed, the manufacture of cotton textiles is rapidly becoming the leading industry.[3]

A peculiar feature of the coast is noticeable in the wave-formed spits or barrier beaches of this region. How do



COAL GIVES THE POSSIBILITY OF MAKING STEEL

these barrier beaches affect commerce? Explain how the barrier beach, with the enclosed lagoon, finally becomes a part of the Coast Plain. The soil of these beaches produces a cotton fibre of long staple and great strength, and this is their chief product. The fibre is used in the web of bicycle-tires.

The montane part of this section is low and not very rugged in the northern, but much higher in the southern part. The Appalachian folds contain the most productive coal measures in the world, and for this reason they are the seat of extensive iron and steel manufactures.

In a few instances the iron ore occurs in the vicinity of the coal measures, but in most instances cheap transportation by water enables the manufacturer to ship the ore to

THE CHIEF GRAIN FIELD OF THE WORLD

the coal mines at a minimum of expense. In a few localities, the coal shipped by canal meets the iron ore brought in steamers and barges from the Lake Superior iron mines to the shores of Lakes Erie and Michigan, and great steel-making plants have grown up at Chicago, Cleveland, Lorain, Toledo, Ashtabula, and Buffalo.

From the foregoing it is apparent that the entire Appalachian region, both folds and plateaus, is an area of manufacture because of certain geographic conditions, and these

are the existence of power. The waterfall is stored-up power and so also is the coal. The power within the coal not only makes the steam that drives so much machinery, but in the smelting furnace it also separates the iron from the ore; and inasmuch as iron and steel form the basis of most manufactures, the existence of coal implies the development of a great centre of manufacture.[4]

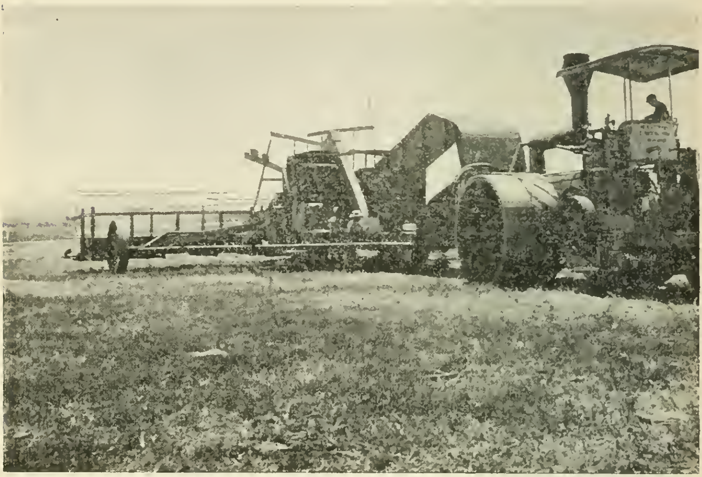
The Great Central Plain.—From Hudson Bay to the Gulf of Mexico the Great Central Plain is characterized by a level or a gently rolling surface, sloping on each side toward the Mississippi River—the whole declining gently from a slight rise, called the Heights of the Land, to the Bay on the north and the Gulf on the south. Trace the Heights of the Land on the map, p. 353. Within what limit of elevation is the greater part of its surface? What is the general elevation west of the Missouri River?

Most of the rivers flow in channels that are from one hundred to three hundred feet lower than the general level of the land, and their high banks are the *bluffs* of this region. For the greater part of their extent the bluffs are not less than one or two miles apart, and there is a very level flood plain between them — the famous "bottom lands." All through the Great Central Plain the soil is naturally very fertile; that of the bottom lands is especially productive.

The level surface and the general conditions of topography make this region one of sameness so far as external appearance is concerned. Climatic conditions, however, make two separate and distinct areas of history and industry; therefore it is divided into Northern States and Southern States. The two groups are roughly separated by a boundary formerly known as "Mason and Dixon's line," and this boundary in former years was sharply defined. Incidentally it was a boundary between "free

States" and "slave States," but the real boundary was one that separated the cotton-growing region from that in which food-stuffs and manufactured goods were the staple products.

In the Northern States wheat, corn, oats, and grass have always been the chief products. Because of the level surface and the deep, nutritious soil the grain crops can



A MODERN HARVESTER

It could not be used in a rugged country.

be both planted and harvested at the minimum of expense. Under no other conditions of topography could there have been such a wonderful development of planting and harvesting machinery. As a result, this region has become one of the principal food-producing regions of the world. It produces one-fourth of the world's crop of wheat, a considerable proportion of the dairy products, and about three-fourths of the corn, most of the latter being fed to hogs and converted into pork.

The western part of this region—the part beyond the 2000-foot contour—does not receive an amount of rain sufficient to mature grain; but the bunch grass and the alfalfa[5] crops are the food of great herds of cattle. As a result, the Northern States of the Great Central Plain produce the flour and meat not only for the United States, but much of that required by the rest of the world.

The Southern States produce about four-fifths of the world's supply of cotton. Grain can be grown in these States but, acre for acre, the crop does not pay nearly so well as cotton; and cotton cannot be grown north of the line that separates the two groups. The industries and social conditions—and, therefore, the history—of the two sections have differed greatly. How did these conditions encourage slavery in the one group and discourage it in the other?

There has always been a considerable amount of manufacture in both sections, but the manufactured articles have been closely related to the grain and the meat product in the one section, and to cotton-growing in the other. These manufactures, moreover, have been greatly encouraged by the extensive coal measures mainly in the northern section. Most of the cotton is shipped abroad, to be made into textiles elsewhere.

The Western Highlands.—The Western Highlands embrace all that region between the eastern foot of the Rocky, and the western foot of the Sierra Nevada and Cascade Ranges. This region is characterized by ruggedness. The lofty ranges that form the rims of the highland are less than two miles in altitude in few places only. Fremont and South Passes are the chief channels of intercommunication on the eastern side. On the west the Central Pacific Railway crosses the range at an altitude of nearly 10,000 feet. In the north the cañons of Columbia

River and its tributaries afford grades not too difficult for railway communication; on the south the cañons of the Rio Grande, together with San Gorgonio, and Tehachapi Passes—the latter at the southern junction of the Sierra Nevada and Coast Ranges—are the chief routes of commerce.

The ranges of the Rocky Mountains are lofty folds resting each on a core of granitic rocks. The Sierra Nevada

HAGERMANS PASS

The ranges and cañons are a barrier to intercommunication.

and Cascade Ranges are huge blocks of tilted rock with a gentle slope on the west and an abrupt escarpment on the east. The parallel ridges of Nevada and Oregon, commonly called the "Basin Ranges," are excellent examples of block mountains, the upturned edge of the block con-

stituting the range. Here and there are the isolated knolls that form the *laccolites* of which the Henry Mountains are examples.

The western slopes of the Sierra Nevada and Cascade Ranges receive a generous rainfall; consult the wind chart, p. 221, and explain why. Within the rim ranges the rainfall is deficient. In the northern part it is sufficient for a rather scanty pasturage, but the southern part, the higher plateaus excepted, is a desert.

The Columbia Plateau, or "Plains of the Columbia," is mainly the surface of the great flood of lava that seems to have flowed from several fissures on the Sierra Nevada Mountains.[6] The general surface of the plateau, the block ranges excepted, is fairly level, but the region has been much dissected by the rivers, whose cañons are from five hundred to more than three thousand feet deep.

The Colorado Plateaus, sometimes called the "Alcove Lands," consist of a series of table-lands varying from half a mile to a mile and a half in altitude. The lower plateaus are desert regions of tropical temperature, with here and there a few tribes of squalid Indians. The middle plateaus have sufficient rain for a very scanty covering of grass; the higher mesas have a fair growth of grass and timber.

Cañons with angular outlines and almost vertical walls are the chief characteristic of this region. The cañons of the Colorado, which have made the region famous, in places are more than a mile deep. Probably nowhere else on the face of the earth are the features of erosion and corrosion presented on such a stupendous scale. Every master stream and every tributary is practically an underground stream, so deep are their channels below the general level of the plateaus.

The Basin Region receives its name from the fact that none of its drainage reaches the sea. On the slopes of the

block ranges the rivers are vigorous streams, but their waters finally disappear by evaporation and percolation in the sea of fine rock waste at their bases.[7] The lakes are without outlet to the sea, and most of them are the shrunken remnants of two great lakes that once covered a large part of this region.

One of these, now called Lake la Hontan, included Humboldt, Pyramid, Winnemucca, and several other lakes adjacent. Several of them, including Walker and Owens Lakes, have never wholly disappeared and their waters are saturated brines, evaporation continuing until the water can hold no more saline matter in solution. Great Salt, Utah, Sevier, and Parowan Lakes are the remnants of former Lake Bonneville (p. 173). Of the various remnants half a dozen have wholly disappeared, and Sevier and Parowan Lakes are practically dry. Utah Lake is fresh; why? Great Salt Lake at present is shrinking on account of the diversion of its feeders for purposes of irrigation.[8]

Two small areas of the Basin Region are below sea-level. One of these, Salton Lake and its basin, are undoubtedly the former head of the Gulf of California; the other, Death Valley, may have been. The "sink" or dry bed of Salton Lake, also known as Coahuilla Valley, or the Sink of San Felipe, was most likely separated from the present Gulf by the sediments brought down by the Colorado River. The sediments formed a bar or sea-wall across the Gulf and cut it in twain. The upper portion in places has become partly filled with wind-blown rock waste, but its lowest part is about three hundred feet below sea-level. Death Valley, at Kings Springs, is nearly two hundred and fifty feet below mean tide.

Several of the sinks of this region are fed, not by rivers that normally flow into them, but by the overflows of the Colorado River. When more than bank-full, the latter

overflows into the lower land to the westward. Former Salton Lake was an overflow of this character.[9] New and Hardy's Rivers, frequently chartered on maps of this region, are not streams flowing into the Colorado, but out of it. In this locality the river practically flows around the side of a slope; and at times, when its channel is choked with sediment, the water breaks its confining bank and temporarily flows out into the desert.

MOUNT RAINIER

It is the cinder-cone of an extinct volcano.

The climate of the Basin is one of intense heat, and the southern part is tropical. In many places it is a region of dunes swept by simoons, and occasionally deluged by cloudbursts. To the latter are mainly due the sinks and washes of the region. Yuccas, cacti, mezquit (a species of acacia), and gamma, a coarse grass resembling the spinifex of Australia, are the prevailing vegetation of the southern part; sage-brush, a kind of wormwood, is characteristic of the northern region. Wherever irrigation is

possible the soil of the river flood plains is highly productive. In the southern part several species of lizard, among them the "horned toad," abound. A large species, popularly known as the "Gila monster," inhabits the Gila River and is peculiar to this river valley. Herds of deer are found near the head of the Gulf of Colorado; and a few camels, the descendants of imported animals,[10] are running wild along the lower part of the river.

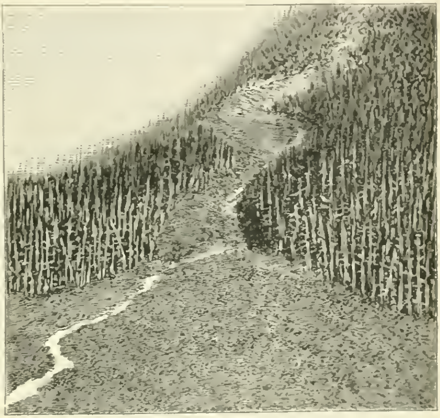
In general, the conditions of both climate and topography will not permit the Western Highlands to become a thickly peopled region. The rainfall is insufficient for the production of food-stuffs, and the latter must depend upon irrigation wherever they are grown. The rugged surface is intensified by the deep and precipitous stream cañons, and these are such obstacles that commerce is carried on only at an enormous expense. In one or two instances a cañon half a mile in width forces traffic to make a detour of several hundred miles around. The mining of copper, lead, and the precious metals is the most important industry.

The Pacific Coast Region.—This region includes the western foot-hills of the Sierra Nevada and Cascade Ranges, the Coast Ranges, and the great intermontane valley between them. The principal feature of this region is the distribution of rain. During the winter months the moist westerly winds are sufficiently chilled to shed an abundance of rain over almost the entire region. Scarcely a drop falls from May to October. The rainfall, therefore, is seasonal.

The foot-hill region is more or less rugged, but the greater part of its area forms excellent ranges for cattle in the north, sheep in the south, and fruit in every part. The Coast Ranges lie abruptly against the shores of the Pacific Ocean and in only a few places is there even

a narrow coast plain. The few harbors, however, are deep, commodious, and most conveniently situated. In a few places, however, vessels lie alongside a high cliff and receive their cargoes by means of chutes with long outriggers. The lower ranges of these mountains form excellent pasturage; the river valleys produce the best wheat that is grown.

The great intermontane valley is probably a marine plain. It varies from twenty to about one hundred miles in width, but in several places it is interrupted by cross spurs that connect the great ranges. In the north, where it opens to the sea, it is known as the Sound Valley. What strait and sound form the outlet? Farther south the Golden Gate opens from the sea into one of the principal harbors of the world; what is its name? This part of the intermontane region is best known as the Sacramento-San Joaquin Valley.



PATH OF A SNOW SLIDE

The northern and southern parts of the intermontane valley form a mammoth wheat field;[11] the middle portion consists of rolling lands that form excellent cattle and sheep ranges, and furnish the possibilities of unlimited water-power not yet utilized. South of Tehachapi Pass a fertile lowland lies next the Pacific which yields an abundance of semi-tropical fruits and a very fine merino wool.

The conditions of both climate and topography make this a region that is capable of supporting an enormous population.

The Territory of Alaska forms the northern part of the Pacific Coast region. Its climate and rugged surface render it unfit for all agricultural pursuits. The coast slope is moderately warm, but the rainy season is about ten months in duration; the interior is a region of arctic temperature. So far as is known there is not a level tract of cultivable land large enough to make a fair-sized farm. The chief wealth of the territory is contained in the gold mines of the Klondike and Cape Nome Districts and in the fisheries of the littoral waters.

The Adjustment of Industrial Pursuits to Environment.—In the growth and development of a nation two processes usually are going on—the acquisition of territory and the adjustment of the pursuits of a people to the conditions of their geographic surroundings. The latter is usually attended with more or less friction, and the friction is a very large factor in their history.

In the geographic distribution of the industries of the United States, one may follow the processes of adjustment. The New England Plateau, with its abundant water-power—helped also by steam-power—furnishes the country with light manufactures and textiles and exports the balance. The people of the harbor region carry on the foreign commerce and largely control the great railway systems that transport the manufacturer's products and the food-stuffs.

The people of the Appalachian region manage the distribution of the coal and supply the country with steel rails, bridge material, building girders, and power-producing machinery. From the prairies of the Great Central Plain come the breadstuffs and meat, and from the Atlantic Coast Plain the fruit and vegetables required for the labor-


City of NEW YORK and Vicinity, with Harbor Approaches.
0 1 2 3 4 5 6
SCALE OF MILES.
Explanation:
Channels:
Light Houses:
Light Vessels:
Lighted Buoys:
Other Buoys:
Borough of the Bronx
Long Island Sound
Borough of Queens
Jamaica
LONG ISLAND
THE PALISADES
Hudson River
Borough of Manhattan
Hoboken
Jersey City
Newark
Newark Bay
Bayonne
North R.
East R.
Governors I.
Upper New York Bay
Robbins Reef Light
Passaic Light
Borough of Brooklyn
Jamaica Bay
Rockaway Beach
18 feet depth
Coney Island
Coney Id. Light
Limit of New York
Elizabeth
Rahway
New Brighton
Port Richmond
Borough of Richmond
Richmond
STATEN ISLAND
NEW JERSEY
Elm Tree Beacon
Lower New York Bay
East Bank
East Channel
Romer Shoal
Gedney Channel
Red Sector
Sandy Hook Light Vessel
ATLANTIC OCEAN
Old Orchard Shoal
Old Orchard Shoal Light
Wreck
Swash Chan.
Flynn's Knoll
South Channel
False Hook
Scotland Light Vessel
Hook Beacon
South Beacon
Sandy Hook
Sandy Hook Bay
Main Chan.
Staten Island Sd.
Great Beds Light
South Amboy
Boundary Beacon
Raritan Bay
Point Comfort Beacon
Waackaack Beacon
Conover Beacon
Lockport
Keyport
Atlantic Highlands
Navesink Lights
Chapel Hill Beacon
Matawan
Red Bank
True North
Magnetic North
Wrecks
East Long Branch
Long Branch
THE M-N CO.

ers in the crowded manufacturing centres. From the south comes the cotton and from the west the wool that is to clothe eighty millions of people. From the Western Highlands are obtained the gold and silver, the medium of commercial exchange, and much of the copper the medium by which electric-power is transmitted. Each section supplies not only the rest of the United States, but a large foreign trade as well.

In general, the area which produces the food-stuffs and timber means great population. The gold and silver mean a vast commerce. The coal and the iron ore are forecasters of tremendous power.

Natural Resources. — No other nation possesses a greater wealth of resources than the United States. Some of these will still last for years, but others are nearly exhausted. The bison and the fur-seal are practically extinct, the former being in part replaced by cattle that certainly are of greater value.

The most valuable *forest trees* of the country are the pines. Of these, a belt of white pine extends along the northern border; and a belt of yellow pine along the Atlantic and Gulf coasts. Both of these regions are nearly exhausted of their supply of merchantable timber.[12] The dense forests of Douglas fir, or "Oregon pine," and redwood of the Pacific Coast will be productive for a much greater length of time. The amount of growing timber is probably greater than at any previous time in the history of the country, but most of it is not adaptable for building purposes. It is estimated that from five to ten million young pines are destroyed each year for use as Christmas trees.

The *coal-fields* cover an area of about 130,000 square miles.[13] Of the amount yielded from these mines, all the anthracite coal comes from three small areas in Pennsylvania; these, it is estimated, will be exhausted in about

one hundred years. The supply of bituminous coal is practically unlimited. Much of the coal-supply is used as house fuel, but by far the greater part is used in the manufacture of iron and in producing steam.

Coal is derived from woody fibre that in time past was subjected to heat and pressure away from contact with the air. Most of the vegetable matter accumulated in the swamps of the Carboniferous Age. The coal measures of the Pacific Coast, however, are of much more recent origin, and formed during the Tertiary period.

Petroleum, or rock oil, occurs in various places, usually

A GATEWAY OF COMMERCE

near but not always in the coal-fields. The refined oil of commerce is shipped to almost every part of the world, and is even an article of caravan trade in Africa. The principal wells of the United States are in Western Pennsylvania, Eastern Ohio, and West Virginia. There is also a productive region in Southern California. Natural gas occurs in the same general area, but the gas and the oil do not seem to be associated. The gas is used for house fuel and for making steam. The supply, much of which has been wasted, is becoming exhausted.

Iron ore occurs in very many parts of the United States,

but it is available only when it can be shipped to places where coal is cheaply obtained. The Gogebic and Keweenaw deposits on Lake Superior, Iron Mountain in Missouri, and the deposits of the Appalachian Mountains are the chief supplies. The iron is obtained from the ore by smelting the latter with coal or coke. The "pig-iron" resulting is then converted into steel ingots by the Bessemer process, and the ingots are rolled into rails, plates, and billets, and other structural material.

Gold is abundant in the Western Highlands. It is obtained mainly by crushing the quartz rock in which it occurs and "amalgamating" or dissolving the gold in quicksilver, or by the use of other solvents. In Alaska and in parts of California most of the gold is free, being mingled with gravel. It is obtained by "washing" the latter away with water, thereby leaving the gold, which is much heavier, to be taken up by the quicksilver. *Silver* also occurs in the Western Highlands. *Copper* occurs in the Rocky Mountains, but the principal part of the product comes from the Lake Superior region. It is mainly used for the transmission of electric power. One of the two quicksilver-producing regions of the world is in California and this state yields about half the output.

QUESTIONS AND EXERCISES.—Repeat the list of physiographic and industrial regions enumerated in the first page of this chapter.

Why is the New England Plateau ill-adapted to grain-farming? How does topography become a factor in the economic production of grain?

State the various ways in which coal is used as power, both on land and at sea.

Study the furniture and equipments of the school-room and make a list of the industries there represented. Trace the geographic source of the raw material employed; where is each manufactured?

Explain how the topography of the northern prairies has affected the development of farming machinery.

Explain why cotton growing is limited to its present latitude. In

what way has cotton-growing affected the social conditions of the people of the Southern States?

Explain how and why the topography of the Western Highlands is a barrier to commerce.

Explain how and why the geographic distribution of industries has resulted in the enormous development of railways.

Describe three railway routes across the Continent; two water routes from Chicago to tide water.

How does the grade of a railway affect the cost of transporting freight?

Obtain from the Hydrographic Office, Washington, D. C., any bulletin or publication explaining the kinds and uses of buoys and range lights employed in harbors.

Trace the course of a deep draught steamship entering the main channel of New York Harbor, with reference to the range lights. (*See map, p. 369.*)

COLLATERAL READING AND REFERENCE

POWELL.—Physiography of the United States, pp. 33–100.

DAVIS.—Physiography of the United States, pp. 269–304.

McGEE.—The Piedmont Plateau, *National Geographic Magazine*, vii., 261.

HEWES.—Statistical Railway Studies, *American Railways*, pp. 425–449.

NOTES

[1] There has been a constant movement of people from the upland farms either to the cities or else to the more fertile regions of the west.

[2] In manufacturing and commercial regions there is a greater amount *per capita* paid for education and higher average daily wages than in any other part of the country.

[3] By manufacturing the cotton in the region where it is grown there is saved the transportation of the cotton from the field to the mills, many miles distant.

[4] The United States now leads in the manufacture of rails. Nearly all of the 6,000 miles of steel rails that span Siberia were made in the rolling mills of Pennsylvania.

[5] Alfalfa is a hardy and rapidly growing species, very closely related to clover. It is fully as nutritious as clover and grows more rapidly.

[6] In several places the Columbia River has cut its channel deep into the flood of lava. In one place there is disclosed a forest which was overwhelmed by the lava. The trees are felled, but the wood is in a good state of preservation.

[7] At times the beds of some of the larger streams, such as Humboldt and Carson Rivers, are dry in the day but contain a considerable amount of water at night, when, by reason of lower temperature, evaporation is lessened.

[8] On the whole there seems to be a slight gain in the volume of the lake. Pyramid, Carson, and Winnemucca Lakes, in recent times dry, are now filling up. Their waters contain not much more than three per cent. of salt.

[9] At the time of the last filling of the basin the water was extremely salt, and its temperature was nearly 120° F. Because of its altitude—more than three hundred feet lower than the Colorado River—at several times there have been propositions to turn the river into the sink and thus make an inland sea. Evaporation is so great, however, that the entire volume of the Colorado would fill but a small part of the basin, nor would there be any outflow from the sink to the Gulf.

[10] The camels were first imported by Jefferson Davis, at the time when he was Secretary of War. As pack animals they were successful. A camel could carry twice as much as the best pack mule, and carry it twice as far in a day. The pack mules and horses were in mortal terror of the camel, however, and the rifle of the packer in time put an end to the experiment—and practically to the camel.

[11] The excess of wheat is exported mainly to Europe, by way of Cape Horn. The completion of the Nicaragua Canal will bring San Francisco nearer to London than its rival wheat market, Calcutta, now is.

[12] Forest fires probably rank first in the destruction of timber. The railways make the heaviest demand on the oak, which is employed as ties. Between the railways and the tanneries the Pennsylvania Appalachians are nearly shorn of oak and hemlock. The paper-makers also use an enormous amount of timber in the manufacture of paper pulp.

[13] Only a small portion of this area, however, is productive. The coal measures of China probably surpass those of the United States.

APPENDIX

I

The Elements of the Solar System

Name.	Distance from Sun, in Miles.[2]	Time of Revolution.	Diameter in Miles.	Number of Satellites.	Density Water = 1
Sun	....	....	860,000	....	1.4
Mercury	37,750,000	88 days	2,992	....	6.8[2]
Venus	66,750,000	224 "	7,660	....	4.8[2]
Earth	92,300,000	365¼ "	7,918	1	5.6
Mars	141,000,000	1.9 yrs.	4,211	2	4.2
Asteroids ...	250,000,000	4.4[1] "	20—300	....	......
Jupiter	480,000,000	11.8 "	86,000	5	1.4
Saturn	881,000,000	29.5 "	70,500	9	0.7
Uranus	1,771,000,000	84 "	31,700[2]	4	1.3[2]
Neptune	2,775,000,000	164 "	34,500[2]	1	1.1[2]

[1] The periodic time of the asteroids varies from 3.1 years to 7.8 years ; the approximate average is 4.4 years.
[2] These values are approximate.

II

Deep Borings

The following are the greatest artificial depths yet obtained, that at Monongahela probably extending as far below sea-level as any others. The two deepest borings in the world were both sunk in Germany, at Government expense, to ascertain the thickness of the coal measures, and also whether other beds underlay those that were known. The deeper of the two and the greatest depth yet attained is in the coal-fields of Upper Silesia, at the little mining town of Paruschowitz, where the diamond drill has penetrated to the depth of 6,570 feet.

The second greatest depth is that at Schladebach, near Leipsic, where the drill was sent down to 6,265 feet. With the exception of the borings on the Monongahela and Wheeling and the deeper of the two wells sunk at St. Louis, all the drilled holes that have reached an exceptionally great depth are in Germany. Here is a list of the deepest bore-holes:

	Feet.
Paruschowitz, Upper Silesia	6,570
Schladebach, near Leipsic	6,265
Monongahela (thus far sunk)	5,532
Wheeling, W. Va	4,920
Sperenberg (gypsum beds near Berlin)	4,559
Lieth, near Altona	4,388
Eu, near Stassfurt	4,241
Lubtheen, in Mecklenburg	3,949
St. Louis, Mo	3,843
Stennewitz, near Halle	3,644
Inowrazlaw, Posen	3,624
Friedrichsaue, near Aschersleben	3,542

Many thousands of wells have been sunk in this country chiefly in the search for petroleum or natural gas, but most of them are not over 1,000 to 2,000 feet deep. The greater part of the artesian wells in the country vary from 200 to 1,000 feet. The average depth of the many thousands of artesian wells sunk for irrigation in the western half of the country is not far from 210 feet.

It is in our copper-mining shafts on Lake Superior that we take first rank in this form of excavation. Work on No. 5 Tamarack shaft on Houghton Peninsula began in 1895, and it will not be completed until 1901, when, it is expected, it will be the deepest shaft in the world. It will not be sunk to a greater depth, for from this level the company can obtain all the ore at that end of its property. There is but little uniformity, however, in the rate at which the heat increases; it varies from one degree (F.) in fifty to one in every seventy or eighty feet of descent. In some cases the heat is due in part to chemical changes in the rock.—*C. C. Adams, in The New York Sun.*

III

Heights of Plateaus, Ranges, and Peaks

Plateaus

	Feet.		Feet.
Abyssinian	6,500— 7,500	Heights of the Land	1,000— 1,500
Allegheny	1,000— 1,500	Iberian	2,000— 2,500
Australian	4,500— 5,500	Iran	5,000— 6,000
Bolivian	12,000—14,000	Mexican	7,000— 8,000
Brazilian	2,800— 2,500	Mongolian	3,000— 4,000
Colorado	4,500— 6,000	New England	1,000— 1,200
Columbia	4,000— 5,000	The "Plains,"	5,000— 6,000
Dekkan	2,000— 2,500	The Pamirs	10,000—14,000
Guiana	2,000— 3,000	Tibet	15,000—17,000

Ranges

	Feet.		Feet.
Alps	7,000— 9,000	Coast (Canada)	4,500— 8,000
Altai	6,000— 7,000	Dragon (So. Africa)	4,000— 5,000
Andes	12,000—15,000	Himalaya	16,000—19,000
Apennines	3,500— 4,000	Hindu Kush	16,000—18,000
Appalachian	1,500— 2,500	Jura	2,500— 3,500
Atlas	8,000—10,000	Karakorum	18,000—19,000
Balkan	4,000— 5,000	Ozark	1,200— 1,500
Blue (Oregon)	4,000— 4,500	Pyrenees	7,500— 9,000
Carpathian	4,500— 6,000	Rocky (U. S.)	6,000— 7,000
Cascade	7,500—10,000	" (Canada)	9,000—10,000
Caucasus	9,000—11,000	Tian Shan	17,000—18,000
Coast (California)	2,500— 3,500	Ural	2,000— 4,000

Peaks

	Feet.		Feet.
Aconcagua	23,900[1]	Fujiyama (volcano)	14,177
Ararat	17,260	Hekla (volcano)	5,100
Blanc	15,744[2]	Hood	11,900
Ben Nevis	4,368[3]	Kenia	18,000
Chimborazo (volcano)	20,500	Kilima Njaro	20,000[8]
Cotopaxi (volcano)	16,300	Kilauea (volcano) Hawaiian Islands	4,000
Dapsang	28,3[illegible]0	Logan	19,500
Demavend (volcano)	18,800	Marcy, New York	5,467[6]
Etna (volcano)	10,875[9]	McKinley, Alaska	20,464[7]
Elbruz	18,526[4]	Mauna Kea (volcano), Hawaiian Islands	14,000
Everest	29,000[5]		
Fremont Peak	13,790		

[1] Highest in South America.
[2] Highest in Europe.
[3] Highest in British Isles.
[4] Highest in Caucasus.
[5] Possibly highest in the world.
[6] Highest in Adirondacks.
[7] Probably highest in North America.
[8] Possibly highest in Africa.
[9] Varies with each eruption.

PEAKS (*Continued*)

	Feet.		Feet.
Mauna Loa (volcano)	13,600	Shasta	14,440
Mitchell, North Carolina	6,711[1]	Sinai	8,600
Hooker, British Columbia	15,700	T. 45 (Himalayas)	29,100[3]
Orizaba (volcano)	18,300[2]	Teneriffe	12,000
Pike's Peak	14,147	Washington	6,286[4]
Popocatepetl (volcano)	17,800	Whitney	14,898[5]
Rainier (Tacoma)	14,441	Vesuvius (volcano)	4,000[6]
St. Elias	18,024	Wrangell	17,500

[1] Highest in Appalachian System.
[2] Highest in Mexico.
[3] Possibly highest in world ; not surveyed.
[4] Highest in White Mountains.
[5] Highest in Sierra Nevada Range.
[6] Varies with each eruption.

IV

LENGTHS OF RIVERS AND AREAS OF THEIR BASINS[1]

	Miles.	Sq. Miles.		Miles.	Sq. Miles.
Amazon	4,000	2,500,000	Murray-Darling	1,100	350,000
Amur	2,500	750,000	Niger	3,000	1,000,000
Brahmaputra	2,000	400,000	Nile	4,000	1,250,000
Colorado	1,100	230,000	Ob	2,800	1,000,000
Columbia	1,400	290,000	Orange	1,200	275,000
Danube	1,800	300,000	Orinoco	1,500	400,000
Dnieper	1,230	200,000	Po	450	27,000
Dwina	700	150,000	Rhine	800	90,000
Elbe	550	450,000	Rhone	550	35,000
Ganges	1,800	450,000	Rio Grande	1,800	200,000
Hoang	2,800	400,000	St. Lawrence	2,100	560,000
Hudson	300	13,000	São Francisco	1,800	200,000
Indus	2,000	350,000	Seine	500	23,000
Irawaddi	1,200	......	Thames	215	6,000
Kongo	3,000	1,500,000	Tocantins[2]	1,000	250,000
La Plata	2,300	1,250,000	Volga	2,300	600,000
Lena	2,800	750,000	Yangtze	3,100	700,000
Mackenzie	2,400	600,000	Yenesei	3,000	1,500,000
Mekong	2,600	300,000	Yukon	2,200	400,000
Mississippi-Missouri	4,200	1,250,000	Zambesi	1,800	500,000

[1] Both the length and the area of the basin are approximate except in a few instances; the length of almost every river changes from year to year.
[2] Not a tributary of the Amazon.

It is well to bear in mind that the length of a river is apt to vary from year to year, partly because of the formation of loops and cut-offs, and partly owing to the gradual extension of its headwater tributaries.

V

Lakes

Name.	Area.	Depth.	Altitude.
	Square Miles.	Feet.	Feet.
Aral	25,000[2]	200[2]	50
Assal	1,000[1]	200	−580
Baikal	13,200	4,500	1,400
Balkash	8,500[2]	135[2]	1,000[1]
Caspian	170,000[2]	3,000[2]	−84
Chad	10,000[2]	20[2]	1,000
Chapala	1,300	....	7,000
Crater	....	2,300	....
Dead Sea	320	700[2]	−1,300
Erie	573	210	9,960
Great Salt	2,300[2]	50[2]	4,200
Huron	23,800	734	581
Ladoga	7,000	730	55
Michigan	22,450	....	581
Nicaragua	2,800	320	108
Salton Lake[2]	....	....	−267
Superior	31,200	1,008	602
Tanganyika	14,000[1]	1,200	2,670
Titicaca	12,500	900	12,500
Victoria	26,000[1]	....	4,000
Winnipeg	9,400	72	710

[1] Approximate; the figures given are from the best authorities, but vary from the measurements of others. Lake Assal is situated in a depression near the Gulf of Aden. It is the head of a small bay severed from the sea by æolian sands. It is fed by a small stream that flows from the sea into the lake. The volume of the lake represents the balance between inflow and evaporation.

[2] Subject to great variations; the sign — prefixed to the altitude indicates below sea-level. Salton Lake is now dry.

VI

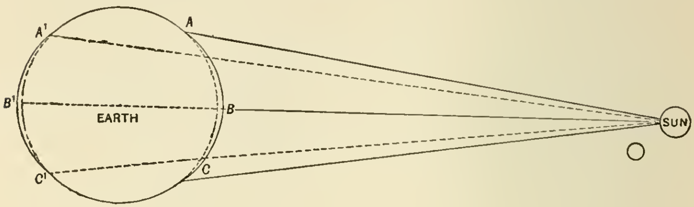
The Tides

The following very clear solution of a much disputed problem is given by Dr. Emerson E. White, author of a series of mathematical text-books. It is only proper to add that no theory on the subject fully explains all the phenomena noted. Dr. White's solution meets the views of most students.

Let E equal the attraction of the earth, and M equal the attraction of the moon at B, and M the attraction of the moon at A and C.

Since distance OB is less than OA or OC, $M > M'$. Hence $E-M<E-M'$, and hence the water at B is *lighter* than at A or C—*i.e.*, has less specific gravity, and is lifted or bulged by the surrounding heavier water.

Let E equal attraction of the earth and m equal attraction of moon at B', and m' equal attraction of moon at A' or C'. Since distance OB' is



greater than OA' or OC', $m < m'$. Hence $E + m < E + m'$, and hence the water at B' is lighter or has less specific gravity than at A' or C' and is lifted or bulged by the surrounding heavier water. Since distance OB is less than OB', $M > m$, and hence the tide at B is higher than at B'.

VII

Table Showing the Number of Grains of Moisture, by Weight Necessary to Saturate a Cubic Foot of Air at Normal Density.

Temperature.	Moisture in One Cubic Foot of Air.	Temperature.	Moisture in One Cubic Foot of Air.	Temperature.	Moisture in One Cubic Foot of Air.
Degrees F.	Grains.	Degrees F.	Grains.	Degrees F.	Grains.
−40	.08	45	3.42	68	7.48
−30	.13	50	4.08	70	7.98
−20	.22	52	4.37	72	8.51
−10	.36	54	4.69	74	9.07
0	.56	56	5.02	76	9.66
10	.87	58	5.37	78	10.28
20	1.32	60	5.75	80	10.94
30	1.96	62	6.14	90	14.79
35	2.37	64	6.56	100	19.92
40	2.85	66	7.01	110	26.43

INDEX